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* Indicates who will present the paper at the meeting.

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PAPERS PRESENTED AT MEETINGS

THIS CALENDAR lists meetings of the Society which have been approved by the Council at which papers may be presented. Programs of Annual Meetings appear in the *Notices* and on the AMS website; programs for sectional meetings appear on the AMS Web pages in the Meetings & Conferences section, and are electronically archived in the *Notices* section on the AMS website.

MEETING #	DATE	PLACE	ABSTRACT DEADLINE	ABSTRACT ISSUE
1106	January 10–13, 2015	San Antonio, TX	EXPIRED	Vol 36, No. 1
1107	March 7–8, 2015	Washington, DC	January 20	Vol 36, No. 2
1108	March 14–15, 2015	East Lansing, MI	January 20	Vol 36, No. 2
1109	March 27–29, 2015	Huntsville, AL	February 4	Vol 36, No. 2
1110	April 18–19, 2015	Las Vegas, NV	February 24	Vol 36, No. 2
1111	June 10–13, 2015	Porto, Portugal	TBA	NONE
1112	October 3–4, 2015	Chicago, IL	August 11	Vol 36, No. 3
1113	October 17–18, 2015	Memphis, TN	August 25	Vol 36, No. 3
1114	October 24–25, 2015	Fullerton, CA	September 1	Vol 36, No. 4
1115	November 14–15, 2015	New Brunswick, NJ	September 22	Vol 36, No. 4

SAN ANTONIO, TX, January 10–13, 2015

Abstracts of the 1106th Meeting.

00 ► General

1106-00-4 **Donald G. Saari*** (dsaari@uci.edu), University of California, Institute Mathematical Beh. Sci., 2119 Social Science Plaza, Irvine, CA 92697-5100. *From Voting Paradoxes to the Search for "Dark Matter".*

Voting Paradoxes are intriguing when demonstrated; frustrating when experienced in actual elections. After offering examples of paradoxical outcomes, a mathematical reason they occur is described. The surprising fact is that this explanation applies to puzzles from other disciplines–including shedding light on the 'dark matter' mystery from astronomy. (Received April 18, 2014)

1106-00-393 **Jessica Bustamante*** (jessica8529@outlook.com). *Dynamical Model of Consumer Rumor Transmission in a Twitter-like Network.*

True or false, consumer rumor (i.e., rumor that targets a company and/or its products) is challenging to control and poses a real threat to company reputation, earnings, and employment. As our title suggests, our talk will discuss the construction and application of a dynamical model of consumer rumor transmission in a Twitter-like network. Twitter is different from most online social networking sites because it allows for communication that is non-symmetric. Using difference equations, rather than differential equations, we determine under what conditions a consumer rumor is likely to infect sufficient nodes to compromise a company's profits. This research was conducted under the supervision of Dr. Janine Wittwer. (Received August 26, 2014)

1106-00-419 **Persi Diaconis***, Department of Statistics, Sequoia Hall, Stanford University, 390 Serra Mall, Stanford, CA 94305-4065. *Applying Applied Math to Algebra.*

Sometimes, the pendulum swings in the other direction: discoveries by applied mathematicians contribute to algebra. I will illustrate with examples from the FFt, illuminating the representation of the Heisenberg group. This is joint work with Dan Bump, Sourav Chatterjee, Angela Hicks, Eric Marberd, and Zhiwei Yun. (Received August 27, 2014)

1106-00-423 **Nomyon Pak*** (nomyon@msn.com), 1270 Nadine Dr., Campbell, CA 95008. *Mathematical study of predation equations.* Preliminary report.

I have accomplished mathematical consideration on predation equations, especially to Watt's and Ivlev's models. (Received August 27, 2014)

1106-00-617 **Joyati Debnath*** (jdebnath@winona.edu), 64 White Oak Court, Winona, MN 55987.
Graph Theoretic Applications on Fingerprint Analysis.

Forensic mathematics has gained importance and popularity over the years among the scientists and professionals. One of them is Fingerprint analysis and graph theoretic application. Fingerprints are commonly used to identify individuals for various purposes. It is known that the early Egyptians, Persians and Chinese used fingerprints to record business transactions. Currently, many graph theoretic algorithms are employed by the forensics to solve crime related events. This project resulted from attending a workshop on Forensics hosted by the Department of Homeland Security (DHS) at Maritime Massachusetts Academy during the summer of 2014. This presentation will focus on how graph theory and fingerprints are connected and the graph theoretic approach of finger print matching will also be discussed. (Received September 03, 2014)

1106-00-626 **Margaret L Rahmoeller*** (mlrahmoe@ncsu.edu). *Some Demazure Crystals for* $U_q\left(A_n^{(1)}\right)$. Preliminary report.

The theory of crystal base provides a combinatorial approach to study representation theory of quantum affine Lie algebras. Demazure modules are certain finite dimensional subspaces of integrable highest weight modules generated by extremal vectors. In this talk we discuss the crystals associated with certain Demazure modules for the quantum affine Lie algebra $U_q\left(A_n^{(1)}\right)$. (Received September 03, 2014)

1106-00-634 **Abigail C Bishop*** (acbishop@ncsu.edu). *Posets Related to Coxeter Groups of type H_2, H_3, and H_4.* Preliminary report.

We will examine both the involution and Bruhat posets of the Coxeter groups H_2, H_3, and H_4. (Received September 08, 2014)

1106-00-757 **Gordan Zitkovic*** (gordanz@math.utexas.edu) and **Pulak Goswami**. *Inferring insider information from trading.*

We analyze a simple model in which the nature of the informational advantage of an insider can be reverse-engineered from his/her trading record. Mathematically, we solve a nonstandard inverse problem for the heat equation and discuss its numerical implementation. (Received September 05, 2014)

1106-00-758 **Sergei Levendorskii*** (levendorskii@gmail.com). *Ghost Calibration and Pricing Barrier Options and CDSs in Spectrally One-Sided Lévy Models: the Parabolic Laplace Inversion Method.*

Recently, the advantages of conformal deformations of the contours of integration in pricing formulas were demonstrated in the context of wide classes of Lévy models and the Heston model. In the present paper we construct efficient conformal deformations of the contours of integration in the pricing formulas for barrier options and CDS in the setting of spectrally one-sided Lévy models. We demonstrate that the proposed method is more accurate than the standard realization of Laplace inversion in many cases. We also exhibit examples in which the standard realization is so unstable that it cannot be used for any choice of the error control parameters. This may lead to a ghost calibration: a situation where a parameter set of a model is declared to be a “good fit’ to the data only because the errors of calibration and of the numerical method used for pricing (almost) cancel each other out. (Received September 05, 2014)

1106-00-759 **Svetlana Boyarchenko*** (sboyarch@eco.utexas.edu) and **Sergei Levendorskii**.
Barrier Options, CDS and Quanto CDS in Lévy Models with Stochastic Interest Rate.

Recently, advantages of conformal deformations of the contours of integration in pricing formulas for European options have been demonstrated in the context of wide classes of Lévy models, the Heston model and other affine models. Similar deformations were used in one-factor Lévy models, where the Wiener-Hopf factorization is applicable, to price options with barrier and lookback features and CDSs. In the present paper, we generalize this approach to models of structural default with the stochastic interest rate, and design an algorithm which is almost as fast as in the case of the constant interest rate. Similar results are obtained for quanto CDS, where an additional stochastic factor: the exchange rate is introduced. (Received September 05, 2014)

1106-00-760 **Rafael Mendoza-Arriaga*** (rafael.mendoza-arriaga@mccombs.utexas.edu), **Lingfei Li**, **Daniel Mitchell** and **Zhiyu Mo**. *Modeling electricity prices: a time change approach.*

We develop a new framework for modeling electricity spot prices by time changing the basic affine jump diffusion, which successfully captures seasonal spikes. Our model is easy to estimate from data and it is tractable for pricing electricity derivatives (Received September 05, 2014)

1106-00-765 **Long Zhao*** (zhaolong.soul@gmail.com). *Storage valuation.*
Using moving boundary method to find the optimal buying and selling strategy in order to get the value of the storage (Received September 06, 2014)

1106-00-774 **Chris D. Lynd*** (clynd@bloomu.edu) and **Devyn A. Lesher**. *Convergence Results for the Class of Periodic Left Nested Radicals.*
We will begin by providing a variety of examples of left and right nested radicals as we present a brief history of this topic and illustrate its connection to difference equations. Then, we will present four new theorems about left nested radicals. In one theorem, we give the necessary and sufficient conditions for the convergence of a periodic left nested radical of a general form. In another theorem, we demonstrate how to construct a sequence of left nested radicals that converges to a predetermined periodic sequence. We conclude the presentation by constructing a sequence of left nested radicals whose limiting sequence repeats the digits in the phone number 867-5309. (Received September 06, 2014)

1106-00-826 **Fawn P Nguyen*** (fawnpnguyen@gmail.com), 720 Owens River Drive, Oxnard, CA 93036. *Establishing and Maintaining a Math Teachers Circle.*
From writing grants to planning sessions to reaching teachers, running a viable Math Teachers Circle (MTC) is a challenging and rewarding charge for our core team. This presentation outlines three key structures that have helped us establish and sustain teacher participation for our MTC in Thousand Oaks in California.

The first structure is planning – how we set up individual and collective duties for our 5-member team of three mathematicians and two middle school teachers. The second is delivering mathematics content and pedagogy – how we seek questions that are of "low-entry and high-exit" for teachers to explore and apply to their own classrooms. The third structure is about building community. This might be the least well defined structure and yet the most critical in sustaining a healthy and thriving MTC.

The Common Core State Standards and the 8 Mathematical Practices need to become an integral part of MTC. Teachers need to find tangible benefits and value in their participation in MTC as professional development in order to sustain their own involvement. (Received September 07, 2014)

1106-00-1030 **Michael Bauer**, **Xiaowen Chang** and **Michael Conway*** (mbconwa@emory.edu). *Quantifying Option Implications.* Preliminary report.
We introduce relevant financial concepts, and describe how mathematical tools can be used to extract information about the market's expectations and risk preferences from daily, observable options market prices on the S&P 500. This information takes the form of a probability density function, known as the Risk-Neutral Density (RND). This project investigated parametric and nonparametric methods for extracting these RNDs. While neither method proved to be superior, we found that the nonparametric method could be improved. Assuming no prior knowledge, we introduce our major tools, including splines and the Generalized Extreme Value (GEV) Distributions, and show how they can be used in a financial context. Our results are based on the daily implied risk neutral densities that we derived for 3800 days. We used the density curves to analyze various market crashes and events during the past two decades. Using regression, we tried to predict option prices for very short periods, which is new to the literature. We also tried to understand how expectation and risk preferences are incorporated into U.S. stock prices. (Received September 09, 2014)

1106-00-1062 **Judith Covington***, judith.covington@lsus.edu. *Problem Solving in the Classroom.*
How important is problem solving in our teaching? To attempt to answer that question, I will reflect on my experiences with integrating problem solving into math courses for future K-12 teachers. As a result of the increased need to fully engage pre-service teachers in problem solving in my classroom I was lead to create the North Louisiana Math Teachers' Circle. I will share my experiences in creating and sustaining this successful Math Teachers' Circle that focuses on problem solving. (Received September 10, 2014)

1106-00-1181 **X Chang*** (xic58@pitt.edu). *Homotopy and homology theory of the moduli of elliptic curves.*
Elliptic curves have wide connections to areas ranging from modular forms to cryptography. We study the homotopy and homology theory of moduli spaces of elliptic curves, and certain computational problems in elliptic cohomology, elliptic genus and elliptic curve cryptography. (Received September 11, 2014)

1106-00-1272 **Kenichi Shimizu*** (x12005i@math.nagoya-u.ac.jp), Furocho, Chikusaku, Nagoya, Aichi 464-8602, Japan. *Frobenius properties of tensor functors.*
An extension H/K of finite-dimensional Hopf algebras is not a Frobenius extension in general, but a "β-Frobenius extension" in the sense that there is an algebra automorphism β of K, written by using the modular functions

of H and K, such that the K-dual of H is isomorphic to H as a K-H-bimodule if we twist the action of K by β:

$$_K H_H \cong {}_\beta \mathrm{Hom}_K(H_K, K_K)$$

(Fischman-Montgomery-Schneider (1997)). I will talk about a generalization of this result to finite tensor categories: Let $F : \mathcal{C} \to \mathcal{D}$ be a tensor functor between finite tensor categories, and let L and R be a left and a right adjoint ot F, respectively. If F is surjective in the sense that every $V \in \mathcal{D}$ is a quotient of $F(X)$ for some $X \in \mathcal{C}$, then there is an invertible object $\chi_F \in \mathcal{D}$, written by using the distinguished invertible objects of $\mathcal{C}$ and $\mathcal{D}$, such that

$$L(\chi_F \otimes V) \cong R(V) \cong L(V \otimes \chi_F) \quad (V \in \mathcal{D}).$$

(Received September 14, 2014)

1106-00-1306 **Willi Freeden*** (freeden@mathematik.uni-kl.de), MPI -Building 26, Paul-Ehrlich-Strasse, 67663 Kaiserslautern, RP, Germany. *Geosystem Mathematics: Its Role, Its Aim, and Its Potential.*

Current understanding of the highly complex system Earth with its interrelated subsystems and interacting physical, chemical, and biological processes is not only driven by scientific interest but also by a growing public concern about the future of our planet, its climate, its environment, and its resources. Obviously, both aspects, viz. efficient strategies of protection against threats of a changing Earth and the exceptional situation of getting terrestrial, airborne as well as spaceborne data of better and better quantity and quality explain the strong need of new mathematical structures, tools, and methods, i.e., geomathematics.

This overview talk deals with geomathematics, its role, its aim, and its potential. Moreover, the "circuit geosystem mathematics" is exemplified by representative problems. (Received September 12, 2014)

1106-00-1419 **Andrew Lazowski*** (lazowskia@sacredheart.edu), 5151 Park Ave., Fairfield, CT 06825. *Finite Factors of Bernoulli Schemes.*

We consider a k-block presentation of a Bernoulli scheme X and its representation as a directed graph G. A labeling of G defines a finite factor of X. We will explore finitely Markovian finite factors of X. (Received September 12, 2014)

1106-00-1507 **Bren Cavallo** and **Delaram Kahrobaei*** (dkahrobaei@gc.cuny.edu), PhD Program in Computer Science, CUNY Graduate Center, 365 Fifth Ave, New York, NY 10016. *A family of polycyclic groups over which the uniform conjugacy problem is NP-complete.*

In this talk we study the conjugacy problem in polycyclic groups. Our main result is that we construct polycyclic groups G_n whose conjugacy problem is at least as hard as the subset sum problem with n indeterminates. As such, the conjugacy problem over the groups G_n is NP-complete where the parameters of the problem are taken in terms of n and the length of the elements given on input. In 2004 Eick and Kahrobaei proposed polycyclic groups as a secure platform for the commutator key exchange and offered computational evidence. Later Garber, Kahrobaei, and Lam experimentally showed that polycyclic groups were resistant to many of the heuristic attacks that are strong against braid groups. In this word we offer theoretical evidence that the conjugacy decision and search problems over polycyclic groups are difficult.

Reference: B.Cavallo, D.Kahrobaei, A family of polycyclic groups over which the uniform conjugacy problem is NP-complete, IJAC, International Journal of Algebra and Computation 24, no.4, 515-530 (2014) DOI: 10.1142/S0218196714500234. (Received September 13, 2014)

1106-00-1954 **Amanda J. Mangum*** (amangum@niagara.edu) and **Mansoor Haider**. *Self-Organizing Maps for Data Clustering in Acoustic Radiation Force Ultrasound Imaging of Cardiovascular Tissues.* Preliminary report.

Atherosclerosis is a cardiovascular disease in which plaque accumulates along the wall of an artery, altering blood flow and increasing the risk for heart attack or stroke. Acoustic Radiation Force Impulse (ARFI) is an ultrasound imaging technique in which acoustic waves are focused at a point, causing displacement of the tissue that is then tracked over time to measure elastic and viscoelastic material properties from the imaging data. We investigate the application of data clustering algorithms, based on Self-Organizing Maps (SOMs), to ARFI imaging for early detection and characterization of atherosclerotic plaques. In this context, SOMs cluster images based on similar patterns in the data set that are identified via a projection of the data vector space onto a lower dimensional map. This map is obtained in a training phase that utilizes a neighborhood function (which distinguishes SOMs from K-Means) to ensure that neighboring data clusters are more similar than clusters far away from each other (in terms of the map topology). Data was examined from an ex vivo ARFI imaging study on porcine iliac arteries performed at the Gallippi Ultrasound Lab at UNC-Chapel Hill. Extensive analysis of

SOM performance was carried out by training SOMs on combinations of expanded training sets. (Received September 15, 2014)

1106-00-2088 **Delaram Kahrobaei*** (dkahrobaei@gc.cuny.edu), PhD Program in Computer Science, CUNY Graduate Center, 365 Fifth Ave, New York, NY 10016, and **Ha T. Lam** and **Vladimir Shpilrain**. *Public-Key Exchange Using Extensions by Endomorphisms and Matrices over a Galois Field.*

In this talk, I describe a public key exchange protocol based on an extension of a semigroup by automorphisms (more generally, by endomorphisms). One of its special cases is the standard Diffie-Hellman protocol, which is based on a cyclic group. However, when our protocol is used with a non-commutative (semi)group, it acquires several useful features that make it compare favorably to the Diffie-Hellman protocol. Here we suggest a couple of instantiations of our general protocol, with a non-commutative semigroup of matrices over a Galois field as the platform and show that security of the relevant protocols is based on quite different assumptions compared to that of the standard Diffie-Hellman protocol. Our key exchange protocols with this platform are quite efficient, too: with private keys of size 127 bits and public keys of size 1016 bits, the run time is 0.03 s on a typical desktop computer. (Received September 15, 2014)

1106-00-2127 **William Wheeless*** (wbwheele@ncsu.edu). *Additional Symmetries of the Extended Toda Hierarchy.* Preliminary report.

We briefly discuss the motivation for studying the Toda hierarchy and its extension. We then give a short introduction to the Virasoro algebra. Finally, the additional symmetries of the extended Toda hierarchy are given in Lax pair formalism, and the connection between these additional symmetries and the Virasoro algebra are shown. (Received September 15, 2014)

1106-00-2162 **Jordan S. Ellenberg*** (ellenber@math.wisc.edu), Department of Mathematics, University of Wisconsin, 480 Lincoln Drive, Madison, WI 53706. *Combinatorial designs, finite geometries, and beating the lottery.*

From 2005 to 2012, a group of friends who met as MIT undergraduates won over 3 million dollars playing a poorly designed game in the Massachusetts lottery. How did they do it, and how did they get away with it? Their strategy, it turns out, involved the theory of *combinatorial designs*. I'll explain what combinatorial designs are, what they have to do with lotteries, their relation with geometry over finite fields, and the 2014 breakthrough of Peter Keevash that solved one of the major open problems in the subject. (Received September 15, 2014)

1106-00-2221 **Shahriar Shahriari*** (sshahriari@pomona.edu), Pomona College, Department of Mathematics, 610 N. College Ave, Claremnt, CA 91711. *Access to Mathematics. Does it matter? What can we do about it?*

Being successful in mathematics opens up many doors. Access to top colleges and universities, success in STEM fields, and pursuing any of the mathematical sciences as a profession require it. Yet the demographics of our profession, our departments, and our students do not reflect the society as a whole. Is this a problem? Do we, as mathematicians and educators, have a role to play? Drawing from my personal experiences at a selective liberal arts college, I will discuss challenges as well as practical approaches to making mathematics accessible to a wider range of students. (Received September 16, 2014)

1106-00-2251 **James M Haley*** (dparasolick@pointpark.edu), School of Business, 201 Wood St., Pittsburgh, PA 15332. *How Monetary Policy Can Eliminate Economic Chaos.* Preliminary report.

Federal Reserve Chairwoman Yellen has recently warned, “It would be a grave mistake for the Fed to commit to conduct monetary policy according to a mathematical rule... it is utterly necessary for us to provide more monetary policy accommodation than those simple rules would have suggested.” Interestingly, Yellen is guided by simple policy rule as well by keeping interest rates low (high), when the economy is operating below (above) its trend. Instead of stabilizing the economy, the unintended consequence of the Yellen Rule is greater forecasting uncertainty, due to nonlinear feedback. This chaotic evolution of forecast errors can be modeled by applying a Sprott nonlinear dynamical system of financial chaos perturbed by random noise and shocked by excess demand for real money. It can be proven that a simpler monetary policy rule exists, which prudently improves everyone's forecasts by targeting the long and short-term interest rates to equal the same fixed expectation. In this way, the economy can be stabilized. (Received September 16, 2014)

1106-00-2561 **Khanh P Nguyen*** (kpnguyen21@yahoo.com), 12218 North Palm Lake Dr., Houston, TX 77034, and **Zachary Kilpatrick**. *Dynamics of bump attractors in a model of spatial navigation.*

We explore a mathematical model of mammalian neuronal activity during spatial navigation, which takes the form of a neural field. Neural fields are integro-differential equations whose integral describes the connectivity between neurons in a network. Commonly, the kernel of this integral is taken to be distance dependent, so the equation is translational invariant. Activity encoding the remembered location of an animal's position is represented by pulse (bump) solutions to the neural field. By altering the kernel of the integral term, we explore how the architecture of the network impacts the bump's position, breaking the translation invariance of the network. In particular, we study the impact of spatial heterogeneity using perturbation theory, which allows us to derive an effective equation for the dynamics of the bump's position. We uncover two mechanisms that can improve the reliability of a network's position encoding: (a) slower timescales of neural integration and (b) periodic spatial heterogeneity in the connectivity of the network. Our results suggest features of networks in the brain that can improve the way animals encode information about space. (Received September 16, 2014)

1106-00-2838 **Michael George*** (mgorge@bmcc.cuny.edu), 199 Chambers Street, New York, NY 10007, **Annie Y Han** (yhan@bmcc.cuny.edu), 199 Chambers St., New York, NY 10007, and **Yevgeniy Milman** (ymilmen@bmcc.cuny.edu), 199 Chambers St., New YOrk, NY 10007. *The Way to Quantitative Literacy for College Developmental Mathematics Students.*

The problem of perennially low passing rates in developmental mathematics has plagued community colleges with years. Efforts to solve this problem have rarely sought to question the fundamental character of the curriculum itself. Quantitative Literacy offers non-STEM students an alternative path to college level mathematics that may be more suited to their mathematical needs than Elementary Algebra. This paper describes the implementation of Quantitative Literacy at a large inner-city Community College. Students enrolled in the 17 sections of Quantitative Literacy were compared to a matched sample of students from traditional elementary algebra. The students enrolled in Quantitative Literacy in the Spring of 2013 were 175% more likely to have passed a credit-bearing mathematics course one year later, indicating that QL represents a valuable alternative for non-STEM college students placed into algebra level remediation. (Received September 16, 2014)

1106-00-2872 **George F McNulty** (mcnulty@math.sc.edu), **Nieves F McNulty** (nmcnulty@columbiasc.edu) and **Douglas B Meade*** (meade@math.sc.edu). *On the creation of a Mathematics Teachers' Circle, and why you should get involved too.*

The South Carolina High Energy Mathematics Teachers' Circle (SCHEMaTC) was created as a novel and fragile partnership of mathematicians and mathematics educators from Columbia College, the University of South Carolina, and middle school teachers from at-risk schools. Many concerns were addressed, and resolved, through the team's participation in the How to Run a Math Teachers' Circle workshop at AIM in summer 2011. By the time SCHEMaTC officially started in summer 2012, a common theme was identified (problem solving) and funding had been obtained. Each academic year a new cohort of about 15 middle school teachers is welcomed into SCHEMaTC. The year begins with an immersion workshop, continues through the academic year with a four-hour session one Saturday almost every month, and concludes with an emmergence workshop. In this presentation we look back and ahead to address issues such as: Why did we want to start an mathematics teachers' circle? What benefits have been realized by the leaders, the teachers, and their students? Why do we encourage others to consider getting involved with, or starting, a local mathematics teachers' circle? (Received September 16, 2014)

1106-00-2929 **Kailynne E Herron*** (kaikaysimons@gmail.com), Bryan, TX 77802. *Bacteria Growth Using Leslie Matrix Model.*

Population growth of a bacterium, streptococcus pneumonia, was examined. Knowing how fast a bacteria grows is essential in knowing how fast to respond to an infection. The projective population growth was calculated using the Leslie Matrix Model, which requires the fertility rate and survival rate of the bacterium. This study will determine if the Leslie Matrix Model is a model that can correctly predict the population growth of a bacterium. (Received September 17, 2014)

1106-00-2932 **Nakeya D Williams*** (nakeya.williams@usma.edu), West Point, NY 10996. *Mathematical Modeling of Cardiovascular Dynamics during Head-up Tilt.* Preliminary report.

Pulsatile and non-pulsatile models that predict dynamic changes in arterial blood pressure during head-up tilt (HUT) are presented in this work. This study shows how mathematical modeling can be used to predict changes in cardiac contractility and vascular resistance, quantities that cannot be measured invasively, but which are useful to assess the state of the cardiovascular system. The models are rendered patient specific via the use of parameter estimation techniques. This process involves sensitivity analysis, prediction of a subset of identifiable parameters, and nonlinear optimization. Results show that it is possible to identify a subset of model parameters that can be estimated allowing the models to predict changes in arterial blood pressure observed at the level of the carotid bifurcation. It is also shown that a simpler non-pulsatile model can be used in conjunction with other physiological models; yet still portray the same dynamics as the pulsatile model. We also show that an optimal control approach is useful for controlling quantities that effect the cardiovascular system during HUT in comparison to numerical optimization with piece-wise linear splines. (Received September 17, 2014)

01 ► History and biography

1106-01-59 **Bogdan D. Suceava*** (`bsuceava@fullerton.edu`), 800 N State College Blvd, Department of Mathematics, CSUF, 154 McCarthy Hall, Fullerton, CA 92834-6850, and **Isabel M. Serrano**. *Remarks on N. Oresme's Definition of Curvitas.*

In a paper published in 1952, J. L. Coolidge points out that "the first writer to give a hint of the definition of curvature was the fourteenth century writer Nicolas Oresme". Coolidge also comments: "Oresme conceived the curvature of a circle as inversely proportional to the radius; how did he find this out?" This question is the starting point of our investigation. It is established that the Tractatus de configurationibus qualitatum et motuum has been written by Oresme sometime between 1351 and 1355. We study N. Orseme's original work in the scholarly environment of his time. (Received June 06, 2014)

1106-01-89 **Chris Christensen*** (`christensen@nku.edu`). *The Polish Cipher Bureau's Attack on the German Enigma Cipher Machine.* Preliminary report.

During the 1930s, three Polish mathematicians Marian Rejewski, Henryk Zygalski, and Jerzy Rozycki attacked the German Enigma cipher machine and broke Enigma messages. After developing an understanding of Enigma's enciphering algorithm, the Polish mathematicians were able to solve for the wiring of the machine's rotors and to develop several cryptanalytic attacks. This presentation will explore the Polish attack on Enigma. (Received July 07, 2014)

1106-01-122 **J.-P. Jeff Chen*** (`jjchen@stcloudstate.edu`), ECC 226, Department of Mathematics & Statistics, 720 4th Avenue South, St. Cloud, MN 56301. *"Symbolic Algebra" in China.*

Some consider the Jesuit-introduced cossic algebra in the 1690s as the first appearance of symbolic algebra in China. Some credit Jean-François Foucquet for his 1711 manuscript for the emperor, the New Method of Algebra, in which Chinese characters were used to represent variables. The emperor ultimately dismissed this work as utter nonsense in spite of initial enthusiasm. Consequently, the content is not included in the mathematical compendium, The Essence of Numbers and Principles, commissioned by the emperor and published in 1723. Although this work contains sections on operations of the "symbolic" expressions, historians of Chinese mathematics generally consider that symbolic algebra was not part of mathematical practice in China until after the translation of Elements of Algebra in 1859. Recently, we uncovered records of usage of "symbolic algebra" in two early 19th-century treatises. In one case, the text explicitly describes expanding squares of the sum of three terms, squares of fractional expressions, and cancellation of common factors on both sides of an equality. This paper examines the practices of "symbolic algebra" recorded in Chinese mathematical treatises, showing the need to reevaluate the uses and impact of symbolism in algebra in 19th-century China. (Received July 22, 2014)

1106-01-164 **Amy Shell-Gellasch***, 14500 Carrolton Rd, Rockville, MD 20853. *The Schilling Kinematic Models at the Smithsonian.* Preliminary report.

The National Museum of American History (NMAH) houses the Smithsonian's collections of mathematical, computing and computer objects. In my role as a volunteer researcher at NMAH, I research and prepare materials for the on-line collections. One such collection is the late 19th century kinematic models of the German firm of Martin Schilling. The Schilling models were constructed to mechanically produce mathematical curves of use primarily in engineering. Of particular mathematical interest are the linkages used to produce linear motion and the models that produce trochoids, of which the cycloid is the most famous member of the family. (Received August 04, 2014)

1106-01-175 **William Dunham*** (wdunham@sas.upenn.edu). *A Hard(y) Integral.*
A century ago, G. H. Hardy easily stood among the world's foremost mathematicians. In addition, he was a superb writer, a cricket enthusiast, an avowed atheist, and a Cambridge eccentric of the first rank. In this talk, after briefly meeting the man himself, we sample a tiny crumb from his vast analytic feast: the evaluation of an improper integral that should leave calculus fans cheering. (Received August 04, 2014)

1106-01-245 **David R Bellhouse*** (bellhouse@stats.uwo.ca), Dept of Statistical and Actuarial Sciences, University of Western Ontario, London, Ontario N6A 5B7, Canada. *Table Parameter Estimation and Inference in Historical Mathematical Tables.*
The construction of a medieval Islamic astronomical table can depend on parameter values that are often unknown to us today. Estimation of these unknown parameters can indicate the school to which the astronomer who created the table belonged. Three estimation techniques have been used by past historians: least squares, least absolute deviations and least number of errors. These techniques are compared through an examination of the assumptions underlying each technique and through an actual case of parameter estimation in the thirteenth-century Islamic solar equation table from the Zamil Zīj. In terms of the model assumptions that underlay the estimation techniques, the dictum of the statistician George Box is followed, "Essentially, all models are wrong, some are useful." In terms of data analysis, it is suggested that what analysts of these tables should be striving for is simplicity and ease of interpretation of the results. Either least squares or the least absolute deviations criterion is a reasonable criterion to use unless there some unusually large calculated deviations from the given table; in that case least absolute deviations would be preferred since less weight is given to the anomalous values. (Received August 14, 2014)

1106-01-268 **Alejandro R Garciadiego*** (gardan@unam.mx), Caravaggio 24, Col. Nonoalco Mixcoac; Del. Benito Juarez, 03700 Mexico, D. F., Mexico. *Euclid's Elements in Spanish, during the XXth century (part I), Vera's edition.* Preliminary report.
Each particular book (independently of the topic under discussion, its purpose, or the language used) has its own history. The spectrum of these accounts (concerning personal, academic, economic, political, religious and social factors, among others) is extremely wide and open to speculation and metamorphosis. It is logical to suppose, although not necessarily historically accurate, that the sophistication of these chronicles should be in direct proportion to the relevance of the work. At least, this should be the case of those rare volumes labeled as classics that have transcended barriers of times, idioms and cultures. In mathematics, perhaps, the best example is Euclid's Elements. At least in the last five hundred years, this particular book has being printed in a wide variety of formats, addressed to different audiences and with diverse goals. As a consequence, this multiplicity of impressions has forced, in some cultures, to edit definitive versions as close as possible to the 'original' one. I have already discussed some of the characteristics and peculiarities of some editions of the Elements published in Spanish language between the XVI and XVIII centuries. In this talk, I will analyze the editorial efforts of Francisco Vera (1888-1967). (Received August 17, 2014)

1106-01-329 **Peggy Aldrich Kidwell*** (kidwellp@si.edu), MRC 671, NMAH, Smithsonian Institution, P.O. Box 37012, Washington, DC 20013-7012. *Recent Trends in the History of American Mathematics – A Digital Divide?* Preliminary report.
During the past thirty years, rapid change, particularly in electronic technologies associated with the computer, have transformed the mathematical instruments in common use, the development and diffusion of ideas in mathematics and the history of mathematics, and both the availability of and assumptions about the availability of historical resources. These changes challenge mathematicians, historians, and a more general public. Examples from recent work on nineteenth century printed American discussions of the slide rule and on objects in the collections of the Smithsonian's National Museum of American History illustrate these trends. (Received August 22, 2014)

1106-01-343 **Craig Alan Stephenson*** (u.d.muss@gmail.com), C/ Vía Láctea, 1C-3A, Aravaca, 28023 Madrid, Spain. *F.R. Moulton and his plans for a new lunar theory.*
At the beginning of the 20th century Forest Ray Moulton was arguably the leading mathematical-astronomer in the United States. During his approximately 30 years at the University of Chicago, Moulton wrote several introductory books on astronomy and celestial mechanics and is nowadays remembered amongst astronomers as being the co-author of the Chamberlin-Moulton planetesimal hypothesis. However, Moulton's main interest was the three-body problem and much of his research was aimed at gaining an understanding of this problem through the study of its periodic solutions. It is on these investigations, which began with his 1899 PhD thesis

and which culminated over 20 years later with the publication of his book *Periodic Orbits*, that this talk is focused.

After giving a brief introduction to Forest Ray Moulton, I will use his correspondence with the Carnegie Institution of Washington to tell the story of *Periodic Orbits*' long (11-year) road to publication and to show how the research this book contains was initially motivated by his desire to construct a new lunar theory. I will attempt to throw some light on his planned theory and to say something about the mathematical techniques which he employed throughout his research. (Received August 24, 2014)

1106-01-459 **George W Heine*** (gheine@mathnmaps.com). *How Johann Bernoulli Solved a Problem whose Solution was Obvious (Or Was It?).*

Johann Bernoulli's work on the brachistochrone problem, one of the precursors to the calculus of variations, is well known. Here we examine a more obscure work on another problem related to the calculus of variations, that of "Drawing the Shortest Line Between Two Points on an Arbitrary Curved Surface." This was the title of a 1728 communication to the Swedish mathematician Samuel Klingenstierna. After giving his main result, Bernoulli mentions that, as a corollary, the shortest curve on a sphere is a great circle. We put this problem in historical context, discuss Bernoulli's work in detail, and briefly summarize later work by Clairaut and Euler. (Received August 28, 2014)

1106-01-478 **Stanisław Domoradzki** (domoradz@ur.edu.pl), University of Rzeszów, Rzeszów, Poland, and **Małgorzata Stawiska-Friedland*** (stawiska@umich.edu), Mathematical Reviews, 416 Fourth St., Ann Arbor, MI 48103. *PhD recipients and distinguished graduates in mathematics at the Jagiellonian University (Kraków) in the years 1918-1939.* Preliminary report.

We discuss the significance of Jagiellonian University in Kraków in educating students of mathematics in the years 1918-1939. We present PhD recipients and distinguished graduates of that period, their achievements and their later roles in Polish scientific and academic life. (Received August 29, 2014)

1106-01-499 **J. J. Tattersall*** (tat@providence.edu), Department of Mathematics, Providence College, Providence, RI 02918. *Benjamin Finkel and the Ohio Normal University Herald.*

In November 1888, the New York Mathematical Society held its first meeting. Earlier that year, Benjamin Finkel, an undergraduate at Ohio Normal University, began editing a weekly column devoted to mathematical problems and their solutions in the college's newspaper. A few years later, in an effort to improve high school teaching in America, Finkel founded and co-edited with John M. Colaw the *American Mathematical Monthly*, now the official journal of the Mathematical Association of America. We focus on the contributors and their contributions to the mathematical department of the *Ohio Normal University Herald* and the influence of the London-based *Educational Times and Journal of the College of Preceptors* on the column. (Received August 31, 2014)

1106-01-525 **Kathy Clark*** (kclark@fsu.edu), 1114 West Call Street, Tallahassee, FL 32306-4459. *Mathematical problems in the "shoebox collection" of the Paul A.M. Dirac papers at Florida State University: Piecing together parts of the puzzle.*

The Special Collections and Archives Division of the Florida State University Libraries now houses the complete papers of Paul A. M. Dirac (1902 – 1984), who was a faculty member at FSU from 1972 until his death in 1984. We are collaborating with Special Collections and Archives on the digitization and preservation (with the use of MAA funds) of an important subset known as the "shoebox collection." There were three goals for our project. First, we reconstructed the initial evidence found in the collection to describe Dirac's process and general solution of polynomial equations. Second, we compared Dirac's work with the processes and solutions known to be the subject of mathematical training at Cambridge and the University of Bristol when Dirac was a student at each institution. Finally, we sought to highlight interesting mathematical investigations from Dirac's personal papers that will be available as part of the Florida State University Digital Library (FSUDL). In this talk, I will share information about the digital library efforts at FSU, a few details of Dirac's personal and professional life, and an analysis (and in some cases, a reconstruction) of several examples of solving polynomial equations found in the "shoebox collection." (Received September 01, 2014)

1106-01-563 **Chris C Bissell***, chris.bissell@open.ac.uk. *The history and philosophy of mathematics for information engineering.*

By 'mathematics for information engineering' I mean the mathematics used in such engineering disciplines as electronics, controls, signal processing and telecommunications. Such mathematics includes Fourier and Laplace transforms, correlation functions, complex algebra and analysis, and general calculus. But the way engineers developed and used these techniques differs enormously from the way the math has been – and still is – taught in conventional scientific and engineering education. From the first half of the 20th century onwards, graphical techniques such as Bode Plots, Nichols Charts and pole-zero diagrams were used to eliminate calculation and algebraic manipulation, and provide engineers with powerful design tools that transcended the mathematical basis of the analysis. The story of this development offers both an intriguing historical perspective on traditional applicable mathematics, but also a radically different view of the philosophy of mathematics as it developed in a novel technological context. This paper will discuss the historical development of such techniques, present the sometimes extraordinarily beautiful design tools developed, and draw some conclusions for the history and philosophy of mathematics. (Received September 02, 2014)

1106-01-721 **Karen V. H. Parshall*** (khp3k@virginia.edu), Department of Mathematics, University of Virginia, P. O. Box 400137, Charlottesville, VA 22901-4137. *The Stratification of the American Mathematical Community: The MAA and the AMS, 1915-1925.*

The MAA officially came into existence over the course of a two-day-long meeting held on 30-31 December, 1915 in Columbus, Ohio. This talk will examine the impetus behind the formation of the MAA, its founding decade of activities, and the dynamics between the MAA and the AMS over the course of that first decade as each sought more clearly to define its place in the American mathematical landscape. (Received September 05, 2014)

1106-01-770 **Janet Heine Barnett*** (janet.barnett@csupueblo.edu), Department of Mathematics & Physics, Colorado State University - Pueblo, 2200 Bonforte Blvd, Pueblo, CO 81001-4901. *Gaston Darboux: monster-maker par excellence.* Preliminary report.

The drama of the rise of rigor in nineteenth century mathematical analysis has now been widely rehearsed. Notable within this saga is the appearance of functions with features so unexpected (e.g., everywhere continuous but nowhere differentiable) that contemporary critics described them as “bizarre,” “ridiculous,” “pathological,” and even “monsters.” Among those who played the part of a “monster-maker,” one of the most talented and influential was French mathematician Gaston Darboux (1842–1917).

In this talk, we survey Darboux’s mathematical and “backstage” contributions to the development of nineteenth century analysis. We review in particular his 1875 *Mémoire sur les fonctions discontinues*, focusing on Darboux’s discussion and proof of the result now known as “Darboux’s Theorem” (i.e., all derivatives have the intermediate value property). After meeting some of Darboux’s own favorite pet monsters, we examine the role that functions such as these played in setting the scene for the re-shaping of analysis during the latter part of nineteenth century. (Received September 06, 2014)

1106-01-856 **Viktor Blasjo*** (v.n.e.blasjo@uu.nl). *The representation of curves in the early Leibnizian calculus.*

Transcendental curves were the focal point of a profound conflict in late 17th-century mathematics. They were at the heart of remarkable advances in the new fields of infinitesimal calculus and mathematical mechanics, but they also rendered obsolete traditional conceptions of geometrical rigour and method, forcing the boundaries of mathematics as defined by classical Greek and Cartesian geometry to be redrawn. The early development of the calculus was shaped by this tension between the old and the new, and many aspects of the early calculus that seem peculiar to modern eyes are in fact very rational attempts at resolving this forgotten conflict. I shall illustrate this by discussing some aspects of Leibniz’s view of the exponential function, including his classroom-ready, do-it-yourself recipe for how to compute logarithms using nothing but an ordinary necklace chain. (Received September 08, 2014)

1106-01-923 **Marc A Harper*** (marc.harper@gmail.com) and **Dashiell Fryer**. *Characterizations Stationary Extrema with Applications to Finite Population Models.*

We show that thermodynamic methods developed for fluctuation theorems can be used to characterize stationary equilibria of Markov chains. For finite population models, we use the characterization to show that evolutionarily stable states are stationary extrema for large population sizes. We also develop relationships between selection, population size, and mutation that lead to long term stationary stability. (Received September 08, 2014)

1106-01-928 **James T Smith*** (smith@sfsu.edu). *Mathematicians and the 1920 Polish-Soviet War.*

In 1918 World War I ended, the Polish Republic was born, and with it the Polish University of Warsaw. Its students included the future logician Alfred Tarski. This presentation is derived from a new Birkhäuser book about him, coauthored with Andrew and Joanna McFarland. Alfred’s professors included Wacław Sierpiński, Stefan Mazurkiewicz, and Stanisław Leśniewski. The atmosphere in their classes must have been electric. The Poles invaded deep into Soviet Russia in 1919/1920. The Red Army drove them back to the very gates of Warsaw in August, but then collapsed. Those professors played a vital role in that Miracle of the Vistula. This was evidently unknown to Alfred, but the excitement certainly influenced him. The presentation also discusses the wartime role of Alfred's future bride, Maria Witkowska. (Received September 08, 2014)

1106-01-1012 **Tom Altman*** (tom.altman@ucdenver.edu), 1380 Lawrence St. LW 814, Denver, CO 80204. *Journeys of a Mathematician – Mieczyslaw Altman's life story during and after World War II – and his quest to discover the methods that will find the optimal solution.*

Mieczyslaw Altman was born in 1916 in Kutno, Poland. From 1937 until the outbreak of World War II, he studied mathematics at the University of Warsaw. In 1939 he crossed the green border and eventually enrolled at the Lwow University. There, he worked directly under the tutelage of Stefan Banach who, at the time, was the Dean and Chair of the Math Faculty. Under Banach's direction, he decided to focus on functional analysis as the primary area of his research. The influence of Banach, H. Steinhaus and S. Mazur (Altman formed a life-long friendship with the latter two), can be seen throughout Altman's work. While he did not complete his doctorate in Lwow, having barely escaped with his life after the attack on the USSR by Germany in 1941, his war journeys took him to Tashkent, where he finished his PhD.

He held several positions at the IMPAN (1949-69), where he served as the Director of the Numerical Analysis Department (1958-69) and vice-president of the Polish Mathematical Society (1962-1963). Professor Altman was awarded Poland's highest prize in mathematics, the Banach's Prize (1958). He took visiting positions at CalTech (1959-60), the Courant Institute (1960), and Rome (1969-70). In 1970, the Altman family immigrated to the USA. He was a Math Professor at LSU, until 1987. (Received September 09, 2014)

1106-01-1064 **Carl Pomerance***, HB6188, Mathematics Department, Dartmouth College, Hanover, NH 03755. *Letters from the master: My correspondence with Paul Erdős.*

In 1974 the great Hungarian mathematician Paul Erdős wrote to me about a recreational math problem in a recent paper of mine. For the next 20+ years, Erdős and I kept up a lively correspondence. Thinking that these letters might later be of interest to posterity, I faithfully saved them, and I mostly saved photocopies of my replies. Looking back on them now, I see not only the evolution of my own research into the Erdős mold, but also a trove of interesting and largely still unsolved problems. Sometimes I view these undeveloped threads with the guilt of someone who was supposed to have done something, but put it off. I know this is somewhat irrational! In any event, the letters are now available to all at the Archives of American Mathematics, and hopefully others will find them interesting. (Received September 10, 2014)

1106-01-1077 **Joe Diestel*** (1989jdvfw@gmail.com), Mathematics, Kent Sate University, Kent, OH 44242. *Series in Banach Spaces.* Preliminary report.

We will start with the classical theorem about convergent series of real numbers: a convergent series is either unconditionally convergent (in which case it is absolutely convergent) or conditionally convergent(in which case it can be rearranges to converge to any preordained real number. Problems 106 and 122 of the Scottish book address wonder what happens to this theorem in infinite dimensional Banach spaces. The solutions have a storied history with many interesting byproducts. We hope to discuss the solutions as well as take a look at some of the byproducts. (Received September 10, 2014)

1106-01-1120 **Mohammad K. Azarian*** (azarian@evansville.edu), Department of Mathematics, University of Evansville, 1800 Lincoln Avenue, Evansville, IN 47722. *A Medieval Calculation of Sine of One Degree by Ghiyāth al-Dīn Jamshīd Mas'ūd al-Kāshī (d. 1429).* Preliminary report.

Al-Kāshī (also known as Jamshīd Kāshānī) discussed the calculation of sine of one degree in his non-extant treatise Risāla al-watar wa'l jaib ("The Treatise on the Chord and Sine"). Our discussion in this paper will be based on Sharh-i Zaīj-i Ulugh Beg ("Commentaries on the Zaīj-i Ulugh Beg"), by Nizām al-Dīn 'Abd al-'Alī ibn Muhammad ibn Husain al-Bīrjandī (d. 1528). In Chapter II of Book II of the above Zaīj, Bīrjandī commented on Kāshānī's aforementioned treatise, and he presented the calculation of sine of one degree based on Kāshānī's iterative method from Risāla al-watar wa'l jaib. (Received September 10, 2014)

1106-01-1140 **Shigeru Masuda*** (hj9s-msd@asahi-net.or.jp), 2-18-5, Tama-Cho, Fuchu, Tokyo 183-0002, Japan. *La value particulière and the eigenvalue.*

We discuss the coincidence between la valeur particulière (the particular value) and the eigenvalue. The eigenvalue problem is the model of the Schrödinger equations or the quantum equations, namely, the Sturm-Liouville type boundary value problem of heat diffusion is the model of the Schrödinger equations. Sturm and Liouville discuss la valeur particulière, without its corresponding la function particulière / le espace particulière. The nomenclature of eigenvalue and eigenfunction / eigenspace are introduced by Hilbert in 1904. This handlings of la valeuer particulière are traditionally relates to the studies of trigonometric series, secular equations, or the linear partial differential equations, by such as Lagrange, Laplace, Fourier, Poisson, Cauchy. Above all, Cauchy 1823 introduces le espace particulière (the eigenspace) of the fluid motion. Sturm-Liouville follow the proving on trigonometric convergence by Fourier and Poisson and describe the boundary value differential equation of linear second order on the heat diffusion problem from Poisson 1835, which handles previously the eigenvalue problem. Courant-Hilbert contribute the mathematical theory on the eigenvalue problem of the Strum-Liouville type to Schrödinger. (Received September 15, 2014)

1106-01-1156 **Piotr Biler**, **Paweł Krupski**, **Grzegorz Plebanek** and **Wojbor A. Woyczyński*** (`waw@case.edu`), Department of Mathematics, Applied Mathematics and Statistics, Case Western Reserve University, Cleveland, OH 44122. *Lwów of the West: A Brief History of Wrocław's New Scottish Book.*

At the end of World War 2, the Yalta Agreements made Lwów, and Western Ukraine, part of the Soviet Union, and subsequently most of the faculty of the old Polish Jan Casimir University moved 320 miles west to the newly Polish city of Wrocław, in the former German province of Lower Silesia. That included several major figures of the Lwów School of Mathematics such as Hugo Steinhaus and Bronisław Knaster, who revived the Scottish Book tradition at the new University and Polytechnic of Wrocław. Most of the problems, entered in the Book by some of the most prominent mathematicians of the second half of the 20th century, have been reprinted in the journal Colloquium Mathematicum, an initiative of Rector Edward Marczewski. The lecture will present a brief history of the New Scottish Book, and it's role in the evolution of the Polish mathematical community after the war. (Received September 11, 2014) (Received September 11, 2014)

1106-01-1180 **Jan Woleński*** (`wolenski@if.uj.edu.pl`), Mickiewicza 26, PL 34 200 Sucha Beskidzka, Malopolska, Poland. *Polish Mathematical School and the Foundations of Mathematics.*

Polish Mathematical School arose around 1918 Working in set theory, topology and their applications in other branches of mathematics became the central concern of this school. The Janiszewski program put mathematical logic and the foundations of mathematics in the very center of mathematical investigations. Stanislaw Lesniewski and Jan Lukasiewicz organize a powerful logical school at the University of Warsaw; Alred Tarski, one of the greatest logicians in the entire history of this field, became one of the first students of logicians and mathematicians at the University of Warsaw. Warszawa was one of the world capitals in logic and the foundations of mathematics in the interwar period. Logicians and mathematicians of Polish Mathematical School and the Lvov-Warsaw Schools achieved many very important results. Leaving details asise, I would like to point out one feature. Polish Matghematical School joined no school in the foundations: logicism, intuitionism or formalism. According to Polish logicians and mathematicians, mathematics should not be bounded by any philosophical "ism". This attribute essentially contributed to so-called mathematical foundations of mathematics. (Received September 11, 2014)

1106-01-1234 **Della Dumbaugh*** (`ddumbaugh@richmond.edu`), Department of Mathematics, University of Richmond, Richmond, VA 23273. *Recent Trends in the History of American Mathematics: Rethinking Politics.*

Politics in mathematics? In the past century, political decisions (seemingly) far outside the scope of mathematics have influenced the development of the discipline in small and large ways. These choices have not only had an impact on the lives of individual mathematicians but also on the larger community and the creation and diffusion of ideas. Using the lives of Hua Luo-geng and Emil Artin, this talk begins to explore the far-reaching consequences of political decisions made elsewhere on the American mathematical community. (Received September 11, 2014)

1106-01-1369 **Joseph W. Dauben*** (`jdauben@att.net`), Department of History, Herbert H. Lehman College, CUNY, 250 Bedford Park Blvd. West, Bronx, NY 10468. *Ancient Chinese Methods for Determining Square Roots, the Areas of Circles, and Volumes of Pyramids and Spheres.*

The history of ancient Chinese mathematics offers numerous ingenious methods for approximating square roots and determining the areas of circles and volumes of pyramids and spheres, all of which involve aspects of the infinite in various ways. As early as bamboo texts from pre-Qin times to the edition of the comprehensive mathematical classic, the *Nine Chapters*, along with its third-century commentary by Liu Hui, methods evolved from early approximation techniques to arguments offering detailed proofs of the correctness of the results obtained. Diagrams and models served as guides, and precise algorithms could be checked to verify that the results obtained were indeed correct. How these elements of the mathematician's toolkit combined to provide rigorous arguments will be discussed with examples drawn from bamboo texts like the *Shu* (Numbers) and *Suan shu shu* (Book of Numbers and Computations), as well as the *Nine Chapters*. (Received September 12, 2014)

1106-01-1429 **Jacqueline Brannon Giles*** (jbgiles@yahoo.com), 13103 Balarama Drive, Houston, TX 77099. *Mathematics: An Imitation of Life.* Preliminary report.

A discussion of the usefulness of mathematics in the 21st century will include some creative applications of mathematical thinking that enhance discernment and pattern recognition in many areas in life.

The Cox Talbot address gives participants a chance to reflect on the diverse use of mathematical thinking in diverse communities at every echelon of society. Since mathematics is loaded with verbal, symbolic, numerical and graphical representations which imitate structures and processes in life, a few unique uses of mathematical thinking will be shared to inspire appreciation of the beauty and utility of mathematical thinking. (Received September 13, 2014)

1106-01-1432 **V. Frederick Rickey*** (fred.rickey@me.com). *The Life and Logic of Stanisław Leśniewski.* Preliminary report.

Leśniewski (1886–1939) received his Ph.D. in Lwów under the direction of Kazimierz Twardowski in 1912. After spending World War I in Russia, he was appointed, in 1919, professor of the philosophy of mathematics, at the newly reopened University of Warsaw. Starting in 1916 he began developing mereology, a theory of parts and wholes. This was followed by his ontology, a theory of names and it was underpinned by protothetic, a very general theory of deduction with quantifiers over all types of variables.

We shall not describe these theories in any detail, but will concentrate on discussing three of his important contributions: his analysis of Russell's antinomy, his views on definitions, and his precision in describing the rules of procedure for his logical systems. (Received September 13, 2014)

1106-01-1434 **Annette Imhausen*** (warner@em.uni-frankfurt.de), Prof. Dr. Annette Warner (Imhausen), Historisches Seminar, Goethe Universität, Grüneburgplatz 1, 63329 Frankfurt, Germany. *Ancient Egyptian mathematics - questions vs. evidence.*

Research on ancient Egyptian mathematics is based on a small number of extant sources. As a consequence, many questions a modern researcher may have cannot be answered. The talk will present questions that cannot be tackled (and explain why) and give an example of how the available sources may be used to further expand our knowledge on Egyptian mathematics. (Received September 13, 2014)

1106-01-1459 **Stephanie A Dick*** (sadick@fas.harvard.edu), Stephanie Dick, 8 Chauncy Street, Apartment 23, Cambridge, MA 02138. *"Constructing a Mathematical Laboratory": An Early History of Computer Algebra Systems.*

This talk explores how new ways of doing mathematics were made possible by the advent of modern digital computing. Many computer-based techniques now exist for visualizing, exploring, and sometimes solving mathematical problems and they yield new perspectives and practices for mathematical research. Among them are programs like Mathlab, Maxima, and Sage that offer users environments for exploring symbolic and algebraic mathematical systems. Programs like these were made possible at a crucial moment in the history of American computing. The first American computers were made to calculate - they were developed to perform numerical calculations faster and more efficiently than their human and machine predecessors. Many early computing practitioners believed, however, that the true power of computation would instead come from the manipulation of symbolic information by computers. This talk will explore how this changing conception of computers led to the development of a new set of mathematical tools by focusing on the history of MACSYMA, among the earliest large-scale symbolic manipulation systems developed at MIT beginning in the mid 1960s. (Received September 13, 2014)

1106-01-1479 **Jemma Lorenat***, jlorenat@sfu.ca. *Polemics in public: controversies around the principle of duality in early nineteenth century geometry.*

A plagiarism charge in 1827 sparked a public controversy centred between Jean-Victor Poncelet (1788–1867) and Joseph Diez Gergonne (1771–1859) over the origin and applications of the principle of duality in geometry. Over the next three years and through the pages of various journals, monographs, public letters, reviews, reports, and footnotes, vitriol between the antagonists increased as their potential audiences grew. While the historical literature offers valuable resources toward understanding the development, content, and effects of geometric duality, the hostile nature of the exchange seems to have deterred an in-depth textual study of the explicitly polemical writings. We argue that the necessary collective endeavour of beginning and ending this controversy constitutes a case study in the circulation of geometry. In particular, we consider how the duality controversy functioned as a medium of communicating new fundamental principles to a wider audience of practitioners. (Received September 13, 2014)

1106-01-1480 **Colin B. P. McKinney*** (mckinnec@wabash.edu), 301 W Wabash Avenue, Crawfordsville, IN 47933. *The Manuscript Tradition of Eutocius' Commentary on Apollonius'* Conics. Preliminary report.

Eutocius of Ascalon, ca. 500 CE, edited an edition of Apollonius' *Conics*. In doing so, he drew on different published versions of the *Conics* to produce a version better suited for students. However, he also noted in the scholia alternative proofs present in source editions, and paid particularly close attention to the number of arrangements of diagrams. In this talk, I will discuss recent findings from my analysis of diagrams in the principle manuscripts and their relationship to the text. (Received September 13, 2014)

1106-01-1489 **Duncan J. Melville*** (dmelville@stlawu.edu), Dept. of Mathematics, St. Lawrence University, Canton, NY 13617. *New Directions in Mesopotamian Mathematics.*

We will give a brief survey of the current state of knowledge of Mesopotamian mathematics and a summary of recent directions and developments in research. We will highlight some of the most interesting new questions and methodologies including close analysis of shape and size of tablets, increased sensitivity to regional variations in mathematical practice, and development in cross-cultural studies. (Received September 13, 2014)

1106-01-1499 **Toke Knudsen*** (toke.knudsen@oneonta.edu), Department of Math., Comp. Sci., and Stat., SUNY Oneonta, 108 Ravine Parkway, Oneonta, NY 13820. *Jñānarāja's Critique of Bhāskarācārya's Siddhāntaśiromaṇi.*

Jñānarāja, an astronomer from Maharashtra, India, wrote an astronomical treatise, the *Siddhāntasundara*, around 1500 CE. It was the first major work to appear after the *Siddhāntaśiromaṇi* of Bhāskarācārya from 1150 CE, well known for its depth and comprehensiveness. Writing at the beginning of the early modern period, Jñānarāja was perpetuating an ancient tradition of astronomy while addressing the needs of his times. While influenced by the *Siddhāntaśiromaṇi*, especially by the idea of *vāsanā* (mathematical demonstration), Jñānarāja was also critical of some of its assumptions and formulae. For example, Jñānarāja rejects a particular formula because it breaks down on equinoctial days, producing the mathematically meaningless result 0/0. The talk will focus on Jñānarāja's use and critique of Bhāskarācārya's *Siddhāntaśiromaṇi*. Attention will be paid to the different times and milieux of the two astronomers in shaping their treatises. (Received September 13, 2014)

1106-01-1532 **Glen Robert Van Brummelen*** (gvb@questu.ca), Quest University, 3200 University Blvd, Squamish, BC V8B 0N8, Canada. *Trigonometric Methods in Ancient Greece, Medieval Islam, and Early India.* Preliminary report.

Astronomers in Greece, Islam and India all applied what from a modern point of view is the same trigonometry to solve astronomical problems. Nevertheless their conceptions of the functions, their modes of reasoning, their methods of calculation, and the problems they found important diverged substantially from one another. Choosing several sample texts, we shall examine what features of trigonometry the three cultures had in common and where they differed; and we shall consider how these differences affected the development of mathematics and astronomy. (Received September 13, 2014)

1106-01-1760 **Michael B Kac*** (kacxx001@umn.edu), Dept. of Philosophy, University of Minnesota, 831 Heller Hall, 271 19th Ave. S., Minneapolis, MN 55455. *Logic, Language and the Polish School.*

Jan Łukasiewicz (1878-1956) is credited with the development of the functor-first, parenthesis-free formulation of the sentential calculus that has come to be known as Polish notation, and his younger colleague Kazimierz Adjukiewicz (1890-1963) with a means of defining wffs in PN which dispenses with formation rules. The latter, apart from its intrinsic interest, has had influence beyond the narrow confines of logic and mathematics, most particularly in linguistics. I will describe the Adjukiewicz scheme and discuss its relationship to the theory of semantic types, and will also describe (in outline) how this led later to some influential insights into the semantics of natural language. I'll take note of the influence (indirect) of this development on Alfred Tarski, a particularly notable product of the Polish school, and, if time permits, will comment also on the influence of Leśniewski and Tarski on another interesting development in the study of natural language. (Received September 15, 2014)

1106-01-1776 **Tatiana Roque***, Instituto de Matemática-UFRJ, Av. Athos da Silveira Ramos 149, Centro de Tecnologia-Bloco C, Rio de Janeiro, 21941-909, Brazil. *How drawings sprang up in a particular field of celestial mechanics.*

By using the methodology of text networks, I have identified a specific practice of drawings in the end of the 19th and the beginning of the 20th century. Mathematicians and astronomers that made use of periodic orbits to analyze special cases of the three body problem started to draw these curves, what was not usual in similar texts of the same period. By exploring texts published in journals like *Astronomische Nachrichten* or *Bulletin*

Astronomique, I intend to show to what extent this new practice was linked to Poincaré's proposals, who had not himself presented drawings of periodic phenomena, what astonished some of his contemporaries, like Heinrich Hertz.

This expedient of drawings is a question about communicating mathematics that also implies a reflection upon the habits and the professional skills involved in scientific research. The computations and drawings demanded in celestial mechanics became more and more mathematical. As George Darwin remarks, astronomers increasingly needed the skills of professional computers who were also mathematicians. The same problem appears in texts of other scientists. This talk proposes to discuss the role of drawings in the boundary of mathematics and celestial mechanics in the period mentioned. (Received September 15, 2014)

1106-01-1863 **Bruce J. Petrie*** (b.petrie@mail.utoronto.ca). *Natures of curves in the early modern period and the emergence of transcendence.* Preliminary report.

Comparing the classification rules of René Descartes and Leonhard Euler reveals the changing significance of nature to mathematical study. Early modern algebraic and transcendental classifications were intended to describe a mathematical object's nature. This nature was useful to determine which objects were appropriate for geometrical study especially when applied to curves. The development of calculus provided the tools necessary for algebraic analysis to uncouple the study of curves and geometry effectively removing the transcendental barrier. The geometrical purpose of the transcendental classification was rendered obsolete and was replaced by focusing on functional relationships between variables. The nature of mathematical objects inherited this algebraic purpose. (Received September 15, 2014)

1106-01-1931 **Norbert VERDIER*** (norbert.verdier@u-psud.fr), 09, avenue de la division Leclerc, 94234 CACHAN, France. *Mathematical Press and Mathematics in Press (1750-185).*

An international Group of historians of Mathematics works about this Duality: Mathematical Press/Mathematics in Press during the 18 th and the 19th Century. In a fist Part, we will present an overview about a rich historiography. In a second Part, we will give contexts and results described in a book recently published: [Gerini and Verdier, 2014]. In a third Part, we will explain the complicated case of France with encyclopedical Journals, specialized Journals and Journals for Teachers and Students.

Bibliography: L'emergence de la presse mathematique en Europe au 19eme siecle. Formes editoriales et etudes de cas (France, Espagne, Italie, Portugal), Christian Gerini and Norbert Verdier (eds.), "Cahiers de logique e d'epistemologie", N 19, College Publications,Oxford, 2014. (Received September 15, 2014)

1106-01-2389 **Laura E Turner*** (turnerl@newpaltz.edu), Department of Mathematics, State University of New York at New Paltz, 1 Hawk Drive, New Paltz, NY 12561. *Communicating mathematics in the late 19th and early 20th centuries: aims, strategies, messages, politics.*

The creation of a mathematical journal is, on the surface, directed at the communication of mathematical results. So, too, are lectures, textbooks, papers, and sometimes even letters. Yet beneath the surface of such communications one often finds complex aims reaching beyond the mathematical content itself. Establishing lines of communication, for instance, engenders power. And communicating certain kinds of results is a means of establishing one's mathematical "identity". In this talk, we delve into some of the aims and strategies behind communicating mathematics. In particular, we consider the reasons for the creation of *Acta Mathematica*, the first so-called "international" journal of mathematics, and the reasons for which certain individuals published there. We also consider the deliberate shaping of images and identities in mathematics via publications, lectures at conferences, and scientific correspondence. (Received September 16, 2014)

1106-01-2420 **Alma Steingart*** (steingart@fas.harvard.edu), 78 Mount Auburn St., Cambridge, MA 02138. *Mathematical Abstraction from Ancient Greece to the Stone Age.* Preliminary report.

The use of "abstract" as an adjective denoting mathematics dates predominately to the mid-eighteenth century, when it was used as a synonym for pure mathematics and hence in opposition to what at the time was known as "mixed mathematics." Up until then, abstract was primarily used as a verb to describe how mathematical entities are discovered or defined. For example, Aristotle held that that mathematical objects, such as numbers and geometrical figures, were arrived at through a process of removal or taking away. This grammatical move from verb or adverb to adjective is meaningful, as it denotes a shift from the use of abstract as an underlying philosophical conception of mathematics to its use as a distinctive marker that differentiates among various types of mathematical activities. In this talk, I survey how the notion of abstract mathematics has transformed, starting with Aristotle and ending with American mathematicians during the Cold War. Throughout, I ask: what does the definition of abstract mathematics tell us about conceptions of mathematics as a field in each given historical moment? How does it reflect broader cultural trends from French First Republic citizenship to turn of the century modernism to 1950s abstract expressionism? (Received September 16, 2014)

1106-01-2627 **Danuta Ciesielska*** (smciesie@cyfronet.krakow.pl), Institute of Mathematics, Pedagogical University, Podchorazych 2, 30-084 Krakow, Poland. *Alfred Rosenblatt (1880-1947). A first Polish algebraic geometer.* Preliminary report.

Alfred Rosenblatt was born on June 22, 1880 in Kraków. He studied in Vienna, Kraków and Götingen. In 1908 he obtained PhD and in 1913 habilitation in Kraków. Until 1936 Rosenblatt stayed in Kraków unsuccessfully trying to obtained a chair at any Polish university. In 1936 he arrived to Lima, where he obtained the Chair of Astronomy and Geodesic at the UNMSM. Rosenblatt was a founder of *Academia Nacional de Ciencias, Físicas y Naturales*. He spent the first half of the 1947 in the USA and visited *Institute for Advanced Study* in Princeton. He died in Lima on July 8, 1947.

Rosenblatt published at least 263 mathematical papers in many various fields of pure and applied mathematics including: algebraic geometry, theory of analytic function, ordinal and partial differential equations, mathematical physics, three body problem, hydrodynamics but he and his contribution to mathematics remain almost unknown for the general audience. He participated in: Cambridge, Strasbourg, Bologna and Zürich **ICM**, where he presented four talks. His interest in algebraic geometry started during his studies in Göttingen. From 1912 to 1932 he published 32 papers on algebraic geometry. Castelnuovo, Enriques, Severi and Zariski cited his results. (Received September 16, 2014)

1106-01-2689 **Zofia Golab-Meyer*** (zofiagm@gmail.com), Institute of Physics, Jagiellonian University, Krakow, Poland. *Recollections of a mathematician's daughter: a history of 20th century Polish intelligentsia in a nutshell.* Preliminary report.

In my presentation, I will share memories of my father, Stanislaw Golab, who was a professor of mathematics. The history of his life is in many respects typical for families representing the intelligentsia of 20th century Krakow. Born in 1902, Stanislaw Golab married Irena, his university classmate. Both were devoted teachers who had raised generations of mathematicians, Stanislaw teaching at a university and Irena in a women's college. During World War II, Stanislaw was imprisoned in a Nazi concentration camp as a result of the infamous "Sonderaktion Krakau," the aim of which was to eliminate scholars of Krakow's universities. After his release in 1940, he engaged in teaching in the underground university. His life in postwar Poland under the communist regime was also full of dramatic events. The life of Stanislaw Golab demonstrates how important is the teacher-disciple relationship in the formation process of a scholar. It demonstrates also that scholars during a time of life endangerment remained loyal to their ethics as academic teachers. I believe it is necessary to question what can we learn from the history of our parents in order to maintain the quality of education today. (Received September 16, 2014)

1106-01-2706 **Jesse W. Byrne*** (jbyrne@uco.edu), 100 N. University Drive, Edmond, OK 73034, and **Charlotte K. Simmons** (cksimmons@uco.edu), 100 N. University Drive, Edmond, OK 73034. *The Legacy of Dorothea Meagher: A Story of a Remarkable Leader.* Preliminary report.

Born to German immigrants, Dorothea's teaching career began at the age of 16. Assigned initially to teach Home Economics, she quickly informed the principal that she preferred mathematics to "cooking and sewing." As recorded by a university historian, "a lady of considerable importance to Central State University joined the staff in 1925." Indeed, Ms. Meagher was to chair the mathematics department and/or serve as the Dean of Women for the next forty-five years. This talk will examine the lasting and far-reaching impact this remarkable woman had on our institution and the community at large, not the least of which includes a current mathematics department where women comprise forty-five percent of the tenured/tenure-track faculty decades after Ms. Meagher's retirement. We will see that the description of her life as one of "service, dedication, and purpose" was most fitting. (Received September 16, 2014)

1106-01-2817 **Bozenna Pasik-Duncan*** (bozenna@ku.edu), Department of Mathematics, University of Kansas, Lawrence, KS 66045. *Fifty Years Later—Reflections from the Classroom of the First Year Study of Mathematics at Warsaw University.* Preliminary report.

This talk focuses on the legacy of Polish mathematicians and the Polish School of mathematics at Warsaw University in 1965. The author, a first year student of mathematics at that time, will share reflections on: Helena Rasiowa, Stanislaw Mazur, Andrzej Mostowski, and Karol Borsuk and their teaching assistants who became well known mathematicians. Their contributions to different areas of mathematics together with the magic of their intellectual creativity and of unique inspiration will be described. The talk will demonstrate the power and the beauty of mathematics developed and taught by these mathematicians. (Received September 16, 2014)

1106-01-2850 **Dominique Duncan*** (dduncan@math.ucdavis.edu), Department of Mathematics, 3113 Mathematical Sciences Building, UC Davis, One Shields Ave., Davis, CA 94616-8633. *The Legacy of Jerzy Neyman.*

Jerzy Neyman, a Polish-American mathematician and statistician, made revolutionary contributions to statistics, scientific planning, and collaborations between different disciplines. He was called "a principal architect of modern statistics." I heard Neyman's name for the first time many years ago at an applied mathematics conference in Zakopane, Poland and learned that he spent most of his life at the University of California at Berkeley. When I took an advanced statistics course in high school, I learned about the Neyman-Pearson Lemma and its importance in the field. That lemma is used to construct or find the uniformly most powerful level alpha hypothesis test. It provides a systematic method of determining the best critical region for testing one hypothesis versus another. When I was in college at the University of Chicago, in Professor Stigler's "History of Statistics" class, I learned the breadth of Neyman's contributions and the importance of his work in the area of statistics, and furthermore, his philosophy of statistics, its necessity, and the advantage of its applications. Neyman used to say "statistics is the servant to all sciences." (Received September 16, 2014)

03 ► Mathematical logic and foundations

1106-03-143 **Menachem Magidor*** (mensara@savion.huji.ac.il), Institute of Mathematics, Hebrew University of Jerusalem, 91904 Jerusalem, Israel. *Inner models constructed using generalized logics.*

The constructable universe L is built by a series of stages where each successor stage is the set of (first order) definable subsets of the previous stage.The problem with L is that it misses many canonical objects like $0^\sharp$.

One possible attempt to define a rich class of inner models is by imitating the construction of L but using definablility by stronger logic. A classical theorem of Myhill and Scott claims that if we use second order logic we get HOD -The class of sets hereditarily ordinal definable.HOD is not very canonical ,it depends very much on the universe of Set Theory from which we start.

This work (which is joint work with J.Kennedy and J. Vaananen) st udies the inner models we can get by using logics which are between first order logic and second order logic. e.g. The logic of the quantifier $Qx, y\Phi(x, y)$ which means "The formula $\Phi(x, y)$ defines a linear order which has cofinality ω. The model we get is rather canonical (in the presence of large cardinals) and contains many canonically definable objects.

We shall similar results for other extended logics. (Received September 13, 2014)

1106-03-144 **Rehana Patel*** (rehana.patel@olin.edu), Franklin W. Olin College of Engineering, Olin Way, Needham, MA 02492. *Ergodic invariant measures as probabilistic structures.*

Probabilistic constructions are ubiquitous throughout mathematics. How might one formulate a model-theoretic notion of 'probabilistic structure'? One natural formulation is provided by the ergodic S_∞-invariant probability measures on the space of countable structures (with fixed underlying set) in a given countable language; to each such measure is associated a complete and consistent infinitary theory. In this talk I will describe a program, initiated by Nate Ackerman, Cameron Freer and myself, that aims to develop a model theory for such probabilistic structures, and discuss some recent results. (Received September 16, 2014)

1106-03-145 **Anand Pillay*** (anand.pillay.3@nd.edu), University of Notre Dame, Notre Dame, IN 46556. *Topological dynamics and definable groups.*

Topological dynamics is the theory of actions of groups on compact spaces by homeomorphisms. I will discuss recent interactions with model theory, especially with generalized stable group theory. On the one hand notions from topological dynamics supply new inariants for definable groups. On the other hand model theory can provide some new invariants for discrete groups. (Received September 12, 2014)

1106-03-146 **Robin Tucker-Drob*** (rtuckerd@math.rutgers.edu), Rutgers University, Piscataway Township, NJ. *Invariant random subgroups of locally finite groups.*

I will discuss the notion of an invariant random subgroup of a countable group G, focusing largely on the case where G is locally finite. I will also discuss the relationship between the existence of nontrivial ergodic invariant random subgroups, nontrivial characters, and nontrivial ideals in the group algebra. (Received September 16, 2014)

1106-03-147 **Trevor M. Wilson*** (twilson@math.uci.edu), Department of Mathematics, 340 Rowland Hall, University of California, Irvine, CA 92697. *A model of set theory in which every set of reals is universally Baire.*

One way in which large cardinals influence the "small" objects of ordinary mathematics is by implying regularity properties such as Lebesgue measurability for certain simply definable sets of reals. Another closely related application of large cardinals is the construction of models in which *every* set of reals has regularity properties (but the Axiom of Choice fails.) Examples of the latter type include Solovay's model, obtained from an inaccessible cardinal, in which every set of reals has the classical regularity properties; and Woodin's derived model, obtained from infinitely many Woodin cardinals, in which the Axiom of Determinacy holds.

In this talk I will present joint work with Paul Larson and Grigor Sargsyan in which we establish a further result along these lines: If there is a cardinal that is a limit of Woodin cardinals and strong cardinals, then there is a proper class model of ZF in which the Axiom of Determinacy holds and every set of reals is universally Baire. (Received September 09, 2014)

1106-03-148 **Ekaterina Fokina*** (efokina@logic.univie.ac.at), Kurt Gödel Research Center, University of Vienna, Währingerstr. 25, 1090 Vienna, Austria. *Equivalence relations in computable model theory.*

Equivalence relations represent the idea of resemblance between mathematical objects. Especially important among equivalence relations are equality, various kinds of isomorphisms and equimorphisms in different mathematical domains. One of the essential questions is the question of existence, up to an equivalence relation, of mathematical structures with particular properties. Applied to computable model theory, one investigates whether or not a particular structure has a computable presentation, that is, is isomorphic to a computable structure. Equimorphic (bi-embeddable for a suitable notion of embedding) structures in the context of computable model theory have also been studied.

In this talk we will discuss several approaches to study the role of equivalence relations in computable model theory. In particular, within one approach, equivalence relations are used to measure the complexity of classification of computable structures. On the other hand, degrees of atomic diagrams of structures can be used to characterize the inherent complexity of equivalence classes of structures, up to various equivalence relations. We will also discuss how equivalence relations allow one to compare the informational content of universes for effectively given structures. (Received September 14, 2014)

1106-03-149 **Richard A. Shore*** (shore@math.cornell.edu), Cornell University, Ithaca, NY. *The Strength of Determinacy and Turing Determinacy within Second Order Arithmetic.*

We analyze the strength of standard Determinacy principles as well as ones for Turing Determinacy that are provable in (subsystems of) second order arithmetic (equivalently ZFC$^-$). These are all at low levels of the arithmetic hierarchy. We consider three notions of strength. The first is in the sense of reverse mathematics which asks what axioms (e.g. comprehension for Π^1_n formulas) are needed to prove the principles. The second is more traditionally proof theoretic in that we compare principles in terms of consistency strength. The third is recursion or set theoretic in that we want to determine the existence of which ordinals (or better levels of the constructible universe L) are is implied by theses principles. Here the measure is in terms of levels of admissibility (Σ_n replacement) or nonprojectability (Σ_n comprehension axioms).

This is joint work with Antonio Montalbán. (Received September 03, 2014)

1106-03-202 **Bruce E Sagan*** (sagan@math.msu.edu). *Open problems for Catalan number analogues.* Preliminary report.

Consider the version of the Fibonacci numbers satisfying $F_0 = 0$, $F_1 = 1$, and $F_n = F_{n-1}+F_{n-2}$ for $n \geq 2$. Define the nth *Fibotorial* to be $F_n^! = F_1F_2\cdots F_n$. The *Fibononomial coefficients* are the quotients $\binom{n}{k}_F = F_n^!/(F_k^!F_{n-k}^!)$ for $0 \leq k \leq n$. It is not hard to see that these numbers are integers and a simple combinatorial interpretation for them using tilings was given by Sagan and Savage. On hearing about this work, Lou Shapiro asked the following questions. Define the *FiboCatalan numbers* to be $C_{n,F} = \binom{2n}{n}_F/F_{n+1}$. Are these integers? If so, what is a combinatorial interpretation? It is easy to show that the answer to the first question is yes. The second is still open. We give a series of related open problems involving Lucas sequences, q-analogues, rational Catalan numbers, and Catalan numbers for Coxeter groups. (Received August 09, 2014)

1106-03-257 **Omar León Sánchez*** (oleonsan@math.mcmaster.ca), 1280 Main St W, Department of Mathematics and Statistics, McMaster University, Hamilton, Ontario L8S 4L8, Canada.
Differential fields with free operators.

While the theory of fields with free operators developed by Moosa and Scanlon allows for a wide variety of additive operators (such as derivations and endomorphisms), it has the shortcoming that it does not deal with theories where the operators are imposed to commute. In this talk we deal with some situations where commutativity can be imposed. Namely, fields with commuting derivations where the free operators commutes with the derivations. We discuss how to show the existence of a model companion using a new differential lifting lemma: a differential version of Hensel's lemma for local finite algebras. This is joint work with Rahim Moosa. (Received August 15, 2014)

1106-03-417 **Michael J Lieberman*** (mlieberman02@gmail.com), Department of Mathematics and Statistics, Masaryk University, Faculty of Science, Kotlarska 2, Building 8, 61137 Brno, Czech Rep. *Toward A Categorical Model Theory.*

We discuss joint work with Jiří Rosický which aims, broadly speaking, to bridge the ever-narrowing gap between abstract model theory and category theory. In particular, we seek to develop a fragment of the classification theory for AECs in the more general context of accessible categories with concrete directed colimits (essentially AECs without coherence), with several surprising results—a generalization of Boney's recent theorem on tameness under a large cardinal hypothesis follows from work of Makkai and Pare, and these categories admit a robust Ehrenfeucht-Mostowski functor which can be used to mimic certain constructions in AECs. It is noteworthy that these results can be proven without the assumption of coherence, or the reintroduction of syntax via Shelah's Presentation Theorem. On the other hand, this investigation clarifies the situations in which coherence seems genuinely indispensable. (Received August 27, 2014)

1106-03-462 **Gianluca Paolini*** (gianluca.paolini@helsinki.fi) and **Tapani Hyttinen**. *Reduction of Embedded Multivalued Dependence to Dividing in Atomless Boolean Algebras.*

Given a logic L and an independence calculus I for L, we say that a notion of independence is reducible to I if there exists a theory T in the logic L, such that the notion of independence is computable using the independence calculus I with respect to T. The most common forms of independence which occur in nature are probably the following four: i) linear independence, ii) algebraic independence, iii) stochastic independence and iv) embedded multivalued dependence. As known, linear and algebraic independence are reducible to Shelah's forking calculus. Recently, Ben-Yaacov showed that stochastic independence is reducible to the continuous forking calculus in the theory of atomless probability algebras. It comes then natural to ask: what about embedded multivalued dependence? In this talk we show that embedded multivalued dependence is reducible to the first-order dividing calculus in the theory of atomless boolean algebras. A part from its mathematical significance, this result establishes strong connections between independence in database theory and stochastic independence. As indeed, in light of the aforementioned reduction, the latter case of independence can be seen as the measure-theoretic version of the former. (Received August 29, 2014)

1106-03-513 **Åsa Hirvonen*** (asa.hirvonen@helsinki.fi), Department of Mathematics and Statistics, P.O. Box 68, 00014 University of Helsinki, 00014 Helsinki, Finland. *Measuring independence in metric model theory.*

Metric model theory studies structures whose domain is a (complete) metric space. One of the peculiarities with these structures is that allowing for small changes to the structures one enhances the stability theoretic properties of the model classes.

Working in the framework of metric abstract elementary classes (adapted from Shelah's abstract elementary classes) one may generalize the notion of isomorphism, enabling the built in treatment of perturbations and thus making use of the enhanced stability. I will show how one can use this enhancement to develop a measure of dependence in a homogeneous metric abstract elementary class with perturbations that is superstable with respect to a perturbation topology, weakly simple and has complete type spaces. The measure is such that having zero dependence coincides with being independent. Time permitting I will show how this measure of dependence can be used for a criterion for finding pregeometries in M^{eq}.

The talk is based on joint work with Tapani Hyttinen. (Received September 16, 2014)

1106-03-590 **Lokenath Debnath*** (debnathl@utpa.edu), 1201 West University Drive, Edinburg, TX 78539, and **Kanadpriya Basu** (kbasu@utep.edu), 500 West University Avenue, El Paso, TX 79968. *A short history of probability theory and its applications.* Preliminary report.

This paper deals with a brief history of probability theory and its applications to Jacob Bernoulli's famous law of large numbers and theory of errors in observations or measurements. Included are the major contributions of Jacob Bernoulli and Laplace. It is written to pay the tricentennial tribute to Jacob Bernoulli, since the year 2013 marks the tricentennial anniversary of Bernoulli's law of large numbers since its posthumous publication in 1713. Special attention is given to Bayes' celebrated theorem and the famous controversy between the Bayesian and frequentism approaches to probability and statistics. This paper is also written to pay a special tribute to Thomas Bayes since the year 2013 marks the 250th anniversary of Bayes' celebrated work in probability and statistics, since its posthumous publication in 1763. This is followed by a short review of the modern axiomatic theory of probability first created by A.N. Kolmogorov in 1933. (Received September 03, 2014)

1106-03-780 **H. Jerome Keisler*** (keisler@math.wisc.edu). *Definability and Independence in Randomizations.*

This is joint work with Uri Andrews and Isaac Goldbring. The randomization of a complete first order theory T is the complete continuous theory T^R with two sorts, a sort for random elements of models of T, and a sort for events in an underlying probability space. We study definability and independence in models of T^R. (Received September 06, 2014)

1106-03-934 **erik walsberg***, erikw@math.ucla.edu. *Definable Metric Spaces and Definable Equivalence Relations.* Preliminary report.

I will discuss metric spaces which are definable in o-minimal expansions of the real field and definable sets of imaginaries in T-convex expansions of o-minimal structures. Joint work with Ehud Hrushovski. (Received September 08, 2014)

1106-03-1025 **Cameron E. Freer*** (freer@mit.edu). *Infinitary model theory in the study of graphons.*

Graphons provide a notion of limit for sequences of dense graphs, and their study allows the application of analytic tools to classical combinatorial problems. To each graphon, a countable random graph is associated via a canonical sampling procedure. I will discuss various uses of infinitary model theory in examining the connection between graphons and the countable structures that arise in this way. (Received September 09, 2014)

1106-03-1100 **Ioannis Souldatos*** (souldaio@udmercy.edu), 4001 W.McNichols Ave, University of Detroit Mercy, Department of Mathematics, Detroit, MI 48221, and **John Baldwin** and **Martin Koerwien**. *The Joint Embedding Property and Maximal Models.*

We investigate the spectra of joint embedding and of maximal models for an Abstract Elementary Class. It is immediate that if $\boldsymbol{K}$ is an AEC with the full joint embedding property (any two models of any cardinality have a common extension) then $\boldsymbol{K}$ has arbitrarily large models if and only if it no maximal models. We show that without the hypothesis of full joint embedding the implication from arbitrarily large models to no maximal models fails. This is trivial if one just takes disjunctions, but such disjunctions fail joint embedding in $\aleph_0$. We provide counterexamples which satisfy joint embedding on a nonempty initial segment of the cardinals.

Main Theorem If $\langle \lambda_i : i \leq \alpha < \aleph_1 \rangle$ is a strictly increasing sequence of characterizable cardinals, there is an $L_{\omega_1,\omega}$-sentence ψ such that:

(1) The models of ψ satisfy JEP up to λ_0, while JEP fails for all larger cardinals;

(2) AP fails in all infinite cardinals;

(3) There exist $2^{\lambda_i^+}$ nonisomorphic maximal models of ψ in λ_i^+, for all $i \leq \alpha$, but no maximal models in any other cardinality; and

(4) ψ has arbitrarily large models.

(Received September 10, 2014)

1106-03-1174 **James T. Long III*** (jtl209@lehigh.edu), 14 E Packer Ave, Bethlehem, PA 18015, and **Lee J. Stanley** (ljs4@lehigh.edu), 14 E Packer Ave, Bethlehem, PA 18015. *An Introduction to Self-Modifying Infinite-Time Turing Machines.*

In the 1930s, Turing and von Neumann independently proposed models of (finite-time) computation with a notion of "shared memory," that is, a common storage source for programs and their data. Through this mechanism, these models allow for programs which are able to modify their own instructions mid-execution.

To our knowledge, no direct attempts have been made to extend these ideas to the setting of infinitary computability, wherein computations are of potentially transfinite length. In this talk, we propose a generalization of Hamkins and Lewis' infinite-time Turing machine which allows for self-modifying programs, and make the intriguing demonstration that our new model is computationally equivalent to the original model in several different ways. Our results and arguments are seen to nicely parallel those from the classical finite-time setting. We argue that this analogy provides further evidence that the infinite-time Turing machine is the natural model for infinitary computability. (Received September 11, 2014)

1106-03-1187 **Paul B. Larson*** (larsonpb@miamioh.edu), Department of Mathematics, Miami University, Oxford, OH 45056. *Scott processes.*

We present axioms for the class of Scott processes of structures in a given relational language, and use them to reprove two classical theorems on counterexamples to Vaught's Conjecture. The first of these is Leo Harrington's unpublished theorem saying that a counterexample to Vaught's Conjecture has models of cofinally many Scott ranks below ω_2. The second is a theorem of Sacks saying that a counterexample to Vaught's Conjecture has distinct models of the same countable Scott rank. (Received September 11, 2014)

1106-03-1328 **Rahim Moosa*** (rmoosa@uwaterloo.ca), Department of Pure Mathematics, University of Waterloo, 200 University Avenue West, Waterloo, Ontario N2L 3G1, Canada. *Compact complex manifolds with a generic automorphism.* Preliminary report.

Bays, Gavrilovich, and Hils have observed that if CCM denotes the theory of compact complex manifolds in the langauge of complex-analytic sets, then the theory of models of CCM equipped with an automorphism has a model companion, denoted by CCMA. The theory CCMA has the same relationship to meromorphic dynamical systems that ACFA has to rational dynamical systems. I will discuss work-in-progress, joint with Martin Bays and Martin Hils, that begins a systematic study of CCMA as an expansion of ACFA. In particular, we prove the Zilber dichotomy for finite-dimensional minimal types. (Received September 12, 2014)

1106-03-1391 **Philip Wesolek** and **Jay Williams*** (jaywill@caltech.edu), Department of Mathematics, California Institute of Technology, Pasadena, CA 91125. *Chain conditions, elementary amenability, and descriptive set theory.*

We first consider three well-known chain conditions on countable groups and characterize them in terms of well-founded descriptive-set-theoretic trees. Using these characterizations, we demonstrate that the sets of groups defined by these conditions are co-analytic and not Borel. We then adapt our techniques to show elementary amenable groups may be characterized by well-founded descriptive-set-theoretic trees and, therefore, elementary amenability is equivalent to a chain condition. Our characterization again implies the set of elementary amenable groups is co-analytic and non-Borel. As corollary, we obtain a new proof of the existence of finitely generated amenable groups that are not elementary amenable. (Received September 12, 2014)

1106-03-1409 **Francis George*** (francis.george@scranton.edu). *Locally Contractive Maps on Perfect Polish Ultrametric Spaces.*

In this talk I will present my result concerning locally contractive maps defined on perfect Polish ultrametric spaces (i.e. separable complete ultrametric spaces). Specifically, that a perfect compact Polish ultrametric space cannot be contained in its locally contractive image. (Received September 12, 2014)

1106-03-1412 **James Freitag**, University of California, Berkeley, Department of Mathematics, Evans Hall, Berkeley, CA 94720-3840, and **Thomas Scanlon***, University of California, Berkeley, Department of Mathematics, Evans Hall, Berkeley, CA 94720-3840. *Complicated strongly minimal sets from the j-function.*

Using the Schwartzian derivative to convert the inverse of the j-function to a well-defined nonlinear differential constructible function $\chi : \mathbb{A}^1 \to \mathbb{P}^1$ one may consider the sets defined by $\chi(x) = a$ for varying a in a differentially closed field of characteristic zero.

Using a functional transcendence theorem of Pila and Seidenberg's embedding theorem, we show that the fibres of χ are strongly minimal and pairwise orthogonal. Moreover, avoiding the set of constant points, the fibres have trivial forking geometry.

These results answer negatively a long standing problem whether a strongly minimal set with trivial forking geometry in a differentially closed field must have $\aleph_0$-categorical induced structure over its canonical parameters and provide an explicit collection of types with which to construct uncountably many nonisomorphic countable differentially closed fields. Combined with an effective finiteness theorem of Hrushovski and Pillay, these results yield explicit bounds in some problems of André-Oort type raised by Mazur. (Received September 12, 2014)

1106-03-1433 **Mirna Dzamonja*** (m.dzamonja@uea.ac.uk), School of Mathematics, University of East Anglia, University Plain, Norwich Research Park, Norwich, Norfolk NR4 7TJ, United Kingdom. *Modeling isomorphic embeddings between Banach spaces.*

Isometric embeddings between Banach spaces can be modeled by first order model theory, by expressing the fact that the distance is preserved through the requirement that the difference between the distances between the images and that between the originals is smaller than every rational number. When we consider isomorphic embeddings, this first-order tool is no longer at our disposal and we have to deal with the question differently. We shall discuss a model theoretic structure which we have used for this purpose and show how it was applied to calculate the universality number in some classes of Banach spaces. (Received September 13, 2014)

1106-03-1446 **Alexei S Kolesnikov*** (akolesnikov@towson.edu), Department of Mathematics, Towson University, 8000 York Rd., Towson, MD 21252, and **Christopher Lambie-Hanson**. *The Hanf number for amalgamation property.*

We address the problem of computing the Hanf number for the amalgamation property of abstract elementary classes. We define a family of AECs that we call coloring classes. For this family, we show that the Hanf number for the disjoint amalgamation property and the amalgamation property is $\beth_{|L|^+}$, where $|L|$ is the size of the language. The results improve those obtained earlier by Baldwin, Kolesnikov, and Shelah. (Received September 13, 2014)

1106-03-1462 **Joel Nagloo*** (jnagloo@gc.cuny.edu). *The unimodularity conjecture in DCF_0.*

In [1], Freitag and Scanlon showed that the algebraic differential equation satisfied by the j-function defines a non-ω-categorical geometrically trivial strongly minimal set. This provided a counterexample to the ω-categoricity conjecture in DCF_0. In this talk we will look at a weakening of the above conjecture; one arising from the work on the second Painlevé equations [2]:

Conjecture 1. In DCF_0 every geometrically trivial strongly minimal set is unimodular.

After recalling few facts about unimodularity in DCF_0, we will talk about whether the j-function also gives a counterexample to Conjecture 1.

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(Received September 13, 2014)

1106-03-1469 **Michael Makkai*** (michael.makkai@mcgill.ca). *The model theory of first-order logic with dependent sorts.* Preliminary report.

First-order logic with dependent sorts, FOLDS for short, was introduced by the author in 1995. Its syntax is very simple, and by itself the syntax cannot be regarded an original contribution. The main new idea is the notion of FOLDS equivalence. FOLDS removes and generalizes the Fregean identity (equality) notion, accepted as a logical primitive in usual model theory, and it replaces it by FOLDS equivalence, a non-primitive concept that is constructed within the language of FOLDS without any use of the Fregean concept. FOLDS is motivated and applied in category theory, and in particular, for higher-dimensional categories. The talk will present a generalization to FOLDS of Lindstrom's well-known model-theoretical characterization of first-order logic. The generalization replaces the notion of isomorphism, recognized as basic in Lindstrom's original work, by FOLDS equivalence. This generalization necessitates the replacement of the usual syntax of first-order logic with the somewhat more elaborate syntax of FOLDS. The basic outline of Lindstrom's proof is present in the proof of the new result. On the other hand, the use of a categorical language for the formulation and the proof of the new result seems to be unavoidable. (Received September 13, 2014)

1106-03-1625 **Will Boney*** (wboney2@uic.edu). *Up and Out: Frames and tameness in Abstract Elementary Classes.*

Frames are an axiomatic independence notion in a single cardinal for Abstract Elementary Classes developed by Shelah, and tameness is a locality notion for types isolated by Grossberg and VanDieren. Although powerful on their own, they become even more powerful when combined. Tameness provides an easy way to extend frames to larger cardinal, and frames provide a way to extend the tameness for 1-types to tameness for longer tuples. Thus, combining them gives rise to a global notion of independence in an AEC with amalgamation. Part of this talk is joint work with Vasey. (Received September 14, 2014)

1106-03-1631 **Howard Becker*** (becker@math.wisc.edu). *Mazur's game and Choquet's game.*
The study of infinite games originates with a question of Mazur, which is the first of three questions in Problem 43 of The Scottish Book. A variant of Mazur's game was introduced by Choquet. The importance of Choquet's game is that the existence of a winning strategy for Player II is an interesting and useful property. In that sense, the study of this game is in the spirit of the three questions, and different from most subsequent research on infinite games, which is concerned with the determinacy of the game. We discuss: the relationship between the two types of games; using Choquet's game to generalize the metric space concept of completeness to arbitrary topological spaces; applications of Choquet's game in descriptive set theory. (Received September 14, 2014)

1106-03-1646 **Gabriel Conant*** (gconan2@uic.edu). *Urysohn spaces over restricted distance sets.*
Given a countable subset $Ssubseteqmathbb R^{geq 0}$, which contains 0, there is a characterization of the existence of a countable, homogeneous metric space $mathcal U_S$, which has distances only in S, and is universal for finite metric spaces with distances in S. Working from previous results on the complete Urysohn sphere in continuous logic, we develop a model theoretic context for the study of $mathcal U_S$, resulting in characterizations of quantifier elimination, forking independence, stability, and simplicity. We then use tools from model theory to investigate the combinatorial properties of these spaces. In particular, the finitary strong order property provides a concrete combinatorial rank for measuring the complexity of both the theory of $mathcal U_S$, as well as the algebraic structure inherited by the distance set S. The relationship between this algebraic structure and certain kinds of ordered monoids motivates further conjectures and questions, which are of a similar flavor as several interesting problems in additive and algebraic combinatorics. (Received September 16, 2014)

1106-03-1675 **Edward W. Krohne*** (edward.krohne@my.unt.edu), **Su Gao** (sgao@unt.edu), **Steve Jackson** (jackson@unt.edu) and **Brandon Seward** (bseward@umich.edu). *A Characterization of Existence for a Class of Continuous Equivariant Maps to Subshifts of Finite Type.*
Many simple combinatorial questions have corresponding definable analogues, i.e., continuous, measurable, Borel, etc. For example, it is well known that if a topological space is given a Borel graph structure, there may exist graph colorings (e.g., with Choice) that use fewer colors than any definable coloring, i.e., the "definable chromatic number" differs from the classical chromatic number. For the space $F(2^{\mathbb{Z}^2})$ with the shift-action graph (a variation on the Cantor space), we answer a variety of such combinatorial questions, including continuous chromatic number. We answer these questions by providing a necessary and sufficient condition for the existence of a continuous equivariant map to a given subshift of finite type. Specifically, we give a sequence $(X_n)_{n\in\mathbb{N}}$ of subshifts of finite type such that for any subshift of finite type X, there exists a continuous equivariant map $\varphi : F(2^{\mathbb{Z}^2}) \to X$ iff for some n, there is a continuous equivariant map $\varphi_n : X_n \to X$. For a given n, the existence of φ_n is conceptually much simpler than the existence of φ, and can even be determined by a finite search. (Received September 16, 2014)

1106-03-1681 **Eduardo Dueñez*** (eduenez@utsa.edu), Mathematics Department, The University of Texas at San Antonio, San Antonio, TX 78249-0664, and **José Iovino** (jose.iovino@utsa.edu), Mathematics Department, The University of Texas at San Antonio, San Antonio, TX 78249-0664. *Model theory and the Mean Ergodic Theorem for abelian unitary actions.*
Let T be a unitary transformation of a Hilbert space $\mathcal{H}$. Von Neumann's Mean Ergodic Theorem (1932) states that the ergodic averages

$$\mathrm{AV_n}(x) := \frac{1}{n} \lim_{n\to\infty} \sum_{k=1}^{n} T^n(x)$$

as $n \to \infty$, tend, for each $x \in \mathcal{H}$, to the projection $\pi(x)$ of x on the subspace ${}^T\mathcal{H} = \{x \in \mathcal{H} \mid T(x) = x\}$ of fixed elements.

T. Tao (2012, unpublished) has outlined a short proof of the existence of the averages using classical non-standard analysis *à la* Robinson. Using the theory of types over Banach structures, we prove Wiener's 1939 generalization of von Neumann's theorem (for ergodic averages of a unitary representation of an abelian group G on $\mathcal{H}$). Our approach is close to Tao's in spirit, but the use of model-theoretical types captures subtleties easily missed in Robinson's formalism; in particular, our argument requires quantified types as well as types in two variables, and also exploits homogeneity.

We hope to extend these results to obtain a model-theoretical proof of the theorem of M. Walsh (2012) on polynomial ergodic averages. (Received September 15, 2014)

1106-03-1741 **Michael C. Laskowski*** (mcl@math.umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742. *Seeking dividing lines for classes of atomic models.* Preliminary report.

We begin an investigation of the model theory of the class $\mathbf{At_T}$ of atomic models of a countable, complete first-order theory T. We introduce the notion of *pseudo-algebraic closure* which is the appropriate generalization of algebraic closure for this context and identify two countably infinite configurations in terms of this notion. We prove two dual theorems: On one hand, if $\mathbf{At_T}$ admits either of these two configurations, then there are $2^{\aleph_1}$ non-isomorphic atomic models of size $\aleph_1$. On the other hand, if $\mathbf{At_T}$ forbids both of these configurations, then $\mathbf{At_T}$ has a model of size continuum.

This is joint work with John Baldwin and Saharon Shelah. (Received September 15, 2014)

1106-03-1749 **John T Baldwin*** (jbaldwin@uic.edu), John T. Baldwin, Dept of Math. Stat. and C.S M/C 249, UIC 851 S. Morgan, Chicago, IL 60607. *A basic dividing line: Are there arbitrarily large models?* Preliminary report.

An Abstract Elementary Class characterizes a cardinal κ if it has models in κ but no larger. There are a number of examples showing that a complete sentence of $L_{\omega_1,\omega}$ that characterizes a cardinal does not have good structural properties.

For example (Baldwin-Koerwien-Laskowski) There is a family of complete sentences of $L_{\omega_1,\omega}$, ϕ_n for $1 \leq n < \omega$ such that ϕ_n characterizes ϕ_n and all models in $\aleph_n$ are maximal. The class satisfies amalgamation in $\aleph_r$ for $r \leq n-2$, fails in $\aleph_{r-1}$ and trivially satisfies it in $\aleph_r$. If there is a model of ϕ_n in an uncountable cardinal there are the maximal number.

In contrast the work on atomic models makes some of the nonstructure results into a theorem.

Theorem[Baldwin-Laskowski-Shelah:Sept probability 90%] If a complete sentence of $L_{\omega_1,\omega}$ characterizes an $\aleph_\alpha$ for $\alpha > 0$ then it has $2^{\aleph_1}$ models in $\aleph_1$.

This contrasts with Boney's development of 'eventual' structure theory from large cardinal hypotheses. (Received September 15, 2014)

1106-03-1823 **Jana Marikova*** (j-marikova@wiu.edu) and **Masahiro Shiota**. *Geometric measures on definable sets in o-minimal structures.*

Let R be an o-minimal expansion of a real closed field, and let V be the convex hull of $\mathbb{Q}$ in R. We define a measure on the R-definable subsets of V^n. This measure takes values in an ordered semiring, and has various desirable properties. For example, the measure of an interval is its length, and it satisfies a change of variables formula. If the value group of the standard valuation on R is of rank one, then this measure can be extended to a measure on all the bounded definable sets, while maintaining the above properties. (Received September 15, 2014)

1106-03-1937 **James Freitag*** (freitagj@gmail.com), Department of Mathematics, University of California, Berkeley, 970 Evans Hall, Berkeley, CA 94720-3840. *Unlikely intersections and differential algebra.*

We will explain how differential algebra can be used to give effective bounds for the intersection of isogeny classes of transcendental points in products of modular curves with non-weakly special subvarieties. The finiteness results come from doing intersection theoretic computations in jet spaces and from a model theoretic analysis of the differential equation satisfied by the j-function. We will also discuss generalizations of the result to higher dimensional moduli spaces. (Received September 15, 2014)

1106-03-1946 **M Malliaris*** (mem@math.uchicago.edu), Department of Mathematics, University of Chicago, 5734 S. University Avenue, Chicago, IL 60637. *Saturation of ultrapowers and Keisler's order.*

Keisler's order is a large-scale classification program in model theory which gives a means of comparing the complexity of theories via saturation of regular ultrapowers. The order was long thought to have five or six classes. The talk will present a recent theorem of Malliaris and Shelah revising this picture. (Received September 15, 2014)

1106-03-2173 **Ashwini Aroskar*** (aaroskar@umich.edu) and **James Cummings**. *Generalized Limits for Weighted Structures.*

Since the introduction of analytic objects called graphons as dense graph limits by L. Lovász and B. Szegedy, the existence of limits for other discrete structures (for example, directed graphs, k-uniform hypergraphs and bounded degree graphs) has also been shown. Using a correspondence between ultraproduct spaces and Euclidean spaces, we have previously proved the existence of limits for general relational structures. This correspondence also yields interesting combinatorial results, namely Regularity and Removal lemmas for relational structures. We have extended the aforementioned correspondence to measurable functions on the ultraproduct and Euclidean spaces. We can prove the existence of limits for weighted structures (with uniformly bounded weights) and these limits can be seen as generalizations of the limits we have obtained for relational structures. Our primary tool is a theory of measures on ultraproduct spaces introduced by G. Elek and B. Szegedy. (Received September 16, 2014)

1106-03-2207 **Andrés Villaveces*** (avillavecesn@unal.edu.co), Departamento de Matemáticas, Universidad Nacional de Colombia, Bogotá, 111321, Colombia, and **Zaniar Ghadernezhad**. *Around the Small Index Property and Reconstruction of Classes from Automorphism Groups, in Non-Elementary Classes.* Preliminary report.

The problem of reconstructing a structure M from its automorphism group $Aut(M)$ has led to deep interaction between logic, topology, descriptive set theory and group theory, historically. Works of Lascar, Hodges, Shelah among others have reframed the problem as a problem of reconstructing the first order theory of a saturated structure. Results from descriptive set theory have been useful in the countable case, other ideas are useful in the uncountable cases. The "Small Index Property" has isolated a specific instance of "topology reduced to group theory" for the action of the group.

We study versions of the Small Index Property for homogeneous models in abstract elementary classes, and we generalize the issue of reconstruction/interpretation to those contexts. (Received September 16, 2014)

1106-03-2227 **Ali Valizadeh*** (valizadeh.ali@aut.ac.ir), 404 Hafez Ave., Amirkabir Univ. of Tech., Department of Math. & Comp. Sciences, Room 338, 15875-4413 Tehran, Tehran, Iran, and **Massoud Pourmahdian**. *Quantifier Elimination for an Unstable Generic Structure.*

Let L be a language with one ternary relation R. We define a function called predimension on any finite structure in this language in the following way:

$$\delta(A) = |A| - |R^A|.$$

We also define the notion of strong (or closed) embedding for two finite structures of this language as follows: $A \leq^* B$ iff $A \subseteq B$ and for every B' between A and B and not equal to A we have:

$$\delta(A) < \delta(B').$$

The class of all finite L-structures (including the empty set), in which empty is closed, has the amalgamation, joint embedding, and hereditary property; hence, it has a generic model M using the results of Fraise and Hrushovski.

We know that M is unstable and undecidable. We will prove for this structure a quantifier elimination up to certain formulas called closure formulas. This result could also be used to answer the question of finite model property for this structure. (Received September 16, 2014)

1106-03-2249 **Sebastien Vasey*** (sebv@cmu.edu). *Independence in tame abstract elementary classes.*

Good frames are one of the main notions in Shelah's classification theory for abstract elementary classes. Roughly speaking, a good frame describes a local forking-like notion for the class. In Shelah's book, the theory of good frames is developped over hundreds of pages, and many results rely on GCH-like hypotheses and sophisticated combinatorial set theory. We argue that dealing with good frames is much easier if one makes the global assumption of tameness (a locality condition introduced by Grossberg and VanDieren). In particular, we prove ZFC results on the existence of good frames and other forking-like notions in AECs. (Received September 16, 2014)

1106-03-2301 **Rami Grossberg*** (rami@cmu.edu), Department of Mathematical Sciences, Carnegie Mellon Univesity, Pittsburgh, PA 15213. *On the white parts of the map of classification theory for AECs.* Preliminary report.

The notion of Abstract Elementary Class was introduced by Shelah and circulated in 1977 in a preprint of [Sh88] that was published only in 1987. Already in the title of [Sh88] we find the far reaching vision of Shelah: "Classification Theory for AECs", there was little evidence in that paper that a classification theory analogues to what was known already for first-order theories is possible. Around 1980 two important families of conjectures were identified. Despite of much significant progress of our understanding of the subject and several thousands of pages in print on AECs, even the special cases of these conjectures for $L_{\omega 1,\omega}$ are widely open.

In my talk I will emphasize the conjectures, describe some progress and will state several related open problems. (Received September 16, 2014)

1106-03-2337 **Monica M VanDieren*** (vandieren@rmu.edu), Department of Mathematics, Robert Morris University, 6001 University Blvd, Moon Township, PA 15108. *Survey of Tame Abstract Elementary Classes.*

Tame abstract elementary classes were identified over a decade ago. At that time they provided an angle to further develop the classification theory for abstract elementary classes without a reliance on a particular logic. Since then, the classification theory for tame abstract elementary classes has expanded to include categoricity transfer, stability, and superstability theorems. We will survey recent developments. (Received September 16, 2014)

1106-03-2355 **Tyler John Markkanen*** (tmarkkanen@springfieldcollege.edu), Department of Math, Physics, and Comp. Sci., Springfield College, 263 Alden Street, Springfield, MA 01109. *Restricting the Turing degree spectra of structures.* Preliminary report.

The degree spectrum of a structure $\mathfrak{A}$, denoted $\mathrm{DgSp}(\mathfrak{A})$, is the set of Turing degrees of all structures isomorphic to $\mathfrak{A}$, that is, $\mathrm{DgSp}(\mathfrak{A}) = \{\deg_T(\mathfrak{B}) : \mathfrak{A} \cong \mathfrak{B}\}$. In computable model theory and effective algebra, degree spectra are sometimes used to classify different kinds of structures based on their computability-theoretic strength. In this talk, we will give restrictions on the degree spectra of specific classes of structures, including finite-component graphs, equivalence structures, rank-1 torsion-free abelian groups, and daisy graphs. This will lead to a separation of a fifth class, namely linear orders, from each of the other four classes. In particular, for each class $\mathcal{K}$ of structures among the four, we will find a linear order whose degree spectrum cannot be realized by the structures in $\mathcal{K}$. (Received September 16, 2014)

1106-03-2375 **Pedro Zambrano*** (phzambranor@unal.edu.co), Departamento de Matematicas, Universidad Nacional de Colombia, AK 30 45-03, Bogota, DC 111321, and **Will Boney** (wboney2@uic.edu), Department of Mathematics, Statistics, and Computer Science, UIC, 851 S. Morgan Street, Chicago, IL 60607-7045. *Around metric versions of tameness and type-shortness in Metric Abstract Elementary Classes.*

W. Boney proved that tameness in discrete Abstract Elementary Classes (AECs), under suitable assumptions, follows from existence of strongly compact cardinals, which proves the consistency of Shelah's categoricity conjecture in AECs.

M. Lieberman and J. Rosicky proved a similar result in accessible categories, which corresponds to a categorial generalization of both discrete AECs and Metric Abstract Elementary Classes (MAECs). However, their arguments are still discrete.

P. Zambrano studied a metric version of tameness which is enough to prove a stability transfer theorem in MAECs, in a similar way as J. Baldwin, D. Kueker and M. VanDieren did in tame discrete AECs.

In this talk, we will talk about a preliminary study of existence of strongly compact cardinals and metric versions of tameness and type-shortness in MAECs. (Received September 16, 2014)

1106-03-2421 **Rumen D Dimitrov*** (rd-dimitrov@wiu.edu), Department of Mathematics, Western Illinois University, Macomb, IL 61455. *An Automorphism Basis in $\mathcal{L}^*(V_\infty)$.* Preliminary report.

Metakides and Nerode introduced the modern study of the lattice $\mathcal{L}(V_\infty)$ of computably enumerable subspaces of the fully effective countable dimensional vector space V_∞. By $\mathcal{L}^*(V_\infty)$ we denote the lattice $\mathcal{L}(V_\infty)$ modulo $=^*$(finite dimension). The complemented elements of $\mathcal{L}(V_\infty)$ are called decidable spaces. In 1977 Metakides, Nerode, and Shore showed that the space V_∞ has also maximal subspaces. The equivalence classes of the maximal spaces modulo $=^*$ are co-atoms in $\mathcal{L}^*(V_\infty)$. The automorphisms of the lattice $\mathcal{L}^*(V_\infty)$ are not well understood. For example, the question about the number of automorphisms of $\mathcal{L}^*(V_\infty)$ has been open for more than 30 years. Ash and Downey proved that every automorphism of $\mathcal{L}(V_\infty)$ is completely determined by its action on the decidable spaces. In this talk we will prove that the automorphisms of $\mathcal{L}^*(V_\infty)$ are completely determined by their action on the co-atoms of $\mathcal{L}^*(V_\infty)$. (Received September 16, 2014)

1106-03-2591 **Shay A Logan*** (logan110@umn.edu), Philosophy Department, 831 Walter Heller Hall, 271 19th Ave South, Minneapolis, MN 55418. *Abstractionist Categories of Categories.*

The most famous abstraction principle is Frege's Basic Law V:

$$\forall X \forall Y (\S(X) = \S(Y) \Leftrightarrow \forall x (Xx \Leftrightarrow Yx))$$

Which matches each concept to a unique object called its extension. Basic Law V is notoriously unsatisfiable, but consistent restrictions of it are a perennial object of study.

In this talk I present an abstraction principle whose abstracts are functors with sufficiently small domain and codomain. The principle is produced by identifying any two sufficiently well-behaved functions with the same domain that agree on all their **2**-elements.

By identifying the identity functors in the range of this principle with the categories they (intuitively) are the identity functors of, we recover abstractionist categories of categories. The existence of nontrivial models is dependent on the existence of at least two inaccessible cardinals. With this assumption, however, the categories of categories that arise are shown to be finitely complete and co-complete and cartesian closed. The internal structure of a given category $\mathcal{C}$ can be, as usual, recovered by examining functors from small ordinal categories into $\mathcal{C}$. (Received September 16, 2014)

1106-03-2628 **Noah A Hughes*** (hughesna@appstate.edu), Mathematical Sciences, Appalachian State University, 342 Walker Hall, Boone, NC 28680. *Reverse mathematics and marriage problems with unique solutions.*

A marriage problem M consists of a set of boys B, a set of girls G and a relation $R \subset B \times G$ where $(b, g) \in R$ means "boy b knows girl g." A *solution* of the marriage problem is an injection $f : B \to G$ such that for every $b \in B$, $(b, f(b)) \in R$. Using the standard anthropocentric terminology, we see that f assigns a unique spouse to each boy from among his acquaintances.

Work has been done within the program of reverse mathematics to analyze theorems regarding necessary and sufficient conditions for a marriage problem to have a solution. In this talk, we review these results and discuss recently completed work concerning the necessary and sufficient conditions for a marriage problem to have a *unique* solution as well as showing how these new theorems fit within the framework of reverse mathematics. (Received September 16, 2014)

1106-03-2694 **Joachim Mueller-Theys*** (mueller-theys@gmx.de). *Immanent Inconsistency.*

Metalogical extensions incorporate metalogics by means of new logical symbols. Among many other things, they thereby yield a soundness criterion for immanent attempts, which try to reflect provability or truth by means of unary formulae in stock. However, this benchmark cannot be met within sufficiently strong theories—-a further consequence of the Diagonal Lemma. The associated sense of immanent inconsistency (which the author has had so long) was mathematized by Wilfried Buchholz, who actually derived formulae the translation and the negation of which are consequences at the same time. Thus, particularly, the provability predicate cannot really express provability, and the formula Con derived therefrom cannot really state consistency: the Arithmetization of Metamathematics fails, and the 2nd Incompleteness Theorem is untrue, though Con is unprovable. (Received September 16, 2014)

1106-03-2900 **Katalin Bimbó*** (bimbo@ualberta.ca), 2–40 Assiniboia Hall, Department of Philosophy, University of Alberta, Edmonton, Alberta T6G2E7, Canada. *On the decidability of the multiplicative–exponential fragment of linear logic.*

Kripke proved the decidability of the implicational fragment of the logic of relevant implication (see [4]). Other relevance logics have been proved decidable relying on the same method of proof. (See, for example, [3, §§3.6–3.9], [2] and [1].) The decidability problem of the multiplicative–exponential (i.e., intensional) fragment of (classical) linear logic remained open for decades. I show that this fragment is decidable. The proof relies on sequent calculi, and combines appropriate versions of three lemmas, which are often referred to as König's, Kripke's and Curry's.

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1106-03-2911 **James Kuodo Huang*** (jkuodo@gmail.com), P. O. Box 3355, Alhambra, CA 90803. *Hilbert logic and product logic.* Preliminary report.

Hilbert Logic is also called Hilbert Complete Perfect Logic which is first coined by the author in 2005. We can define a Hilbert Logic to be any extension of Boolean logic to accept his "Universal consistent theorem of logic". There are two-valued, three-valued, or multi-valued Hilbert logic. A Hilbert logic may be also related to product logic discovered by the author. A realization of a type of Hilbert logic in a product logic will be given in this paper. (Received September 17, 2014)

05 ► Combinatorics

1106-05-72 **Nathan Cahill**, School of Mathematical Sciences, Rochester Institute of Technology, Rochester, NY 14623, **Anthony Harkin**, School of Mathematical Sciences, Rochester Institute of Technology, Rochester, NY 14623, and **Darren A Narayan*** (dansma@rit.edu), University of Rochester, Rochester, 14627. *Modeling functional connectivity of the brains of athletes.* Preliminary report.

Over the past year the effects of concussions on athletes has gained a greater awareness. Our focus will be on using graph theory to analyze resting state functional MRI scans. In these scans the patient is at rest but the brain is still very active. When regions of the brain are stimulated there is a local influx of blood and oxygen. By monitoring these changes in oxygen levels, we can construct a model of the brain network. In our model two regions of the brain are linked if there is significant correlation in the changes in oxygen levels in the respective regions. We will show how metrics from graph theory, such as clustering coefficients, betweenness centrality, and modularity are used to analyze data from functional MRI scans of football players. (Received June 27, 2014)

1106-05-138 **Thomas J. Savitsky*** (savitsky@gwmail.gwu.edu). *Enumeration of* 2*-Polymatroids on up to Seven Elements.*

A theory of single-element extensions of integer polymatroids analogous to that of matroids is developed. We present an algorithm to generate a catalog of 2-polymatroids, up to isomorphism. When we implemented this algorithm on a computer, obtaining all 2-polymatroids on at most seven elements, we discovered the surprising fact that the number of 2-polymatroids on seven elements fails to be unimodal in rank. (Received July 28, 2014)

1106-05-163 **Joseph Kung*** (kung@unt.edu), 4563 Coyote Point, Denton, TX 76208-3238, and **Gordon Royle**. *Graphs whose flow polynomials factor have only integer roots.*

We determine all the graphs whose flow polynomials have only integer roots. These graphs are exactly those graphs with cocycle matroids isomorphic to cycle matroids of chordal graphs with no $M(K_5)$-restrictions. As the flow polynomial of a planar graph is the chromatic polynomial of its dual graph, we have also determined all planar graphs whose chromatic polynomials have only integer roots. The proof is a conceptual one (requiring some easy inequalities for coefficients of polynomials with only real roots and some matroid theory). (Received August 03, 2014)

1106-05-201 **Lauren Keough*** (s-lkeough1@math.unl.edu), University of Nebraska-Lincoln, Dept. of Math, 203 Avery Hall, PO Box 880130, Lincoln, NE 68588-0130. *Extremal Questions for Matchings.*

In recent years there has been increased interest in extremal problems for "counting" parameters of graphs. For example, the Kahn-Zhao theorem gives an upper bound on the number of independent sets in a d-regular graph. In the same spirit, the Upper Matching Conjecture claims an upper bound on the number of k-matchings in a d-regular graph. We are interested in finding which graphs on n vertices with e edges have the minimum number of matchings.

We first solve this question for bipartite graphs. We show that the lex bipartite graph has the fewest matchings of all sizes among bipartite graphs with fixed part sizes and a given number of edges. To prove this result we use both previously known and previously unknown facts about rook placements in Young diagrams. Then we consider both matchings and matchings of fixed sizes in graphs with a given number vertices and edges. We prove that the graph with the fewest matchings is either the lex or the colex graph. Similarly, for fixed k, the graph with the fewest k-matchings is either the lex or the colex graph. (Received August 09, 2014)

1106-05-207 **Eric Allen Swartz*** (eric.swartz@uwa.edu.au), School of Mathematics and Statistics, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia, and **John Bamberg** and **Cai-Heng Li**. *Highly symmetric generalized quadrangles.*

A generalized quadrangle is a point-line incidence geometry $\mathcal{Q}$ such that (1) any two points lie on at most one line, and (2) given a line ℓ and a point P not incident with ℓ, P is collinear with a unique point of ℓ. An antiflag of a generalized quadrangle is a non-incident point-line pair (P, ℓ), and we say that the generalized quadrangle $\mathcal{Q}$ is antiflag-transitive if the group of collineations (automorphisms that send points to points and lines to lines) is transitive on the set of all antiflags. We prove that if a generalized quadrangle $\mathcal{Q}$ is antiflag-transitive, then

$\mathcal{Q}$ is one of the following: the unique generalized quadrangle of order $(3,5)$, a classical generalized quadrangle, or a dual of one of these. This is part of ongoing, joint work with John Bamberg and Cai-Heng Li. (Received August 10, 2014)

1106-05-216 **Debra Boutin** and **Victoria E Horan*** (`victoria.horan.1@us.af.mil`), Rome, NY 13441. *Identifying Codes on De Bruijn Graphs.* Preliminary report.

De Bruijn graphs are an interesting type of directed graphs. Their vertex set consists of d-ary n-tuples, and a directed edge exists from string X to string Y if and only if the last $(n-1)$ letters of X are the first $(n-1)$ letters of Y, in order. Using basic string operations, many generally NP-hard problems have simple constructions when considered on the class of de Bruijn graphs. In this talk, we consider one such problem: the minimum identifying code problem. The minimum identifying code problem is closely related to the minimum dominating set problem, but includes extra conditions requiring that each vertex in the graph is dominated by a different subset of the dominating set.

This is joint work with Dr. Debra Boutin of Hamilton College. (Received August 11, 2014)

1106-05-223 **Chenxiao Xue*** (`chxue@davidson.edu`) and **Carl Yerger** (`cayerger@davidson.edu`). *Optimal Pebbling on Grids.* Preliminary report.

Given a configuration of pebbles on the vertices of a connected graph G, a *pebbling move* is defined as the removal of two pebbles from some vertex and the placement of one of these on an adjacent vertex. The *pebbling number* of a graph G is the smallest integer k such that for each vertex v and each configuration of k pebbles on G there is a sequence of pebbling moves that places at least one pebble on v. The *optimal pebbling number* of G, denoted $\Pi_{OPT}(G)$, is the least k such that some particular distribution of k pebbles is solvable. In this paper, we strengthen a result of Bunde et al. relating to the optimal pebbling number of the 2 by n square grid by describing all possible optimal configurations. We find the optimal pebbling number for the 3 by n grid and related structures. Finally, we give a bound for the analogue of this question for the infinite square grid. (Received August 12, 2014)

1106-05-251 **Neil J. A. Sloane*** (`njasloane@gmail.com`), 11 South Adelaide Ave, Highland Park, NJ 08904. *Counting ON Cells in Cellular Automata.* Preliminary report.

Not much seems to be known about the problem of determining how many cells are ON in a cellular automaton (CA) when started with a single ON cell, even for quite simple CAs. For the one-dimensional CAs defined by Rules 22, 62, 150 there are formulas, but for Rules 30 and 110 little is known. In two dimensions there are formulas for some CAs (Ulam-Warburton, Maltese Cross, Rule 942, the toothpick structure), and conjectures (Fredkin's Replicator), but in other cases (Holladay-Schrandt, Schrandt-Ulam, Y-toothpicks) there are not even guesses. On the other hand, none of these problems are known to be hard. (Received August 14, 2014)

1106-05-256 **Alexander Garver*** (`garv0102@umn.edu`) and **Gregg Musiker**. *Maximal Green Sequences and Type A Quivers.*

Maximal green sequences are certain mutation sequences of a framed quiver $\widehat{Q}$. Some applications of maximal green sequences include Reading's Cambrian lattices in combinatorics, computations of spectra of BPS states in physics, and quantum dilogarithm identities in representation theory. Maximal green sequences have been studied for many acyclic quivers by Brüstle, Dupont, and Pérotin, by Keller, and by Qiu. We present a method for constructing an explicit maximal green sequence of any type A quiver (i.e. a quiver that is mutation equivalent to an orientation of a type A Dynkin diagram). This is joint work with Gregg Musiker. (Received August 15, 2014)

1106-05-274 **Curtis G Nelson*** (`cnelso42@uwyo.edu`), Department of Mathematics, Ross Hall, Room 205, 1000 E University Ave. Dept. 3036, Laramie, WY 82071, and **Bryan L. Shader**. *Maximal Parter-sets of Matrices Whose Graph is a Tree.*

Given a graph G on n vertices, we define $S(G)$ to be the set of all real symmetric $n \times n$ matrices whose zero-nonzero pattern is given by the edges of G. Let A be a matrix in $S(T)$ for some tree T. Let $A(i)$ be the submatrix of A obtained by deleting the i^{th} row and column of A. Let λ be an eigenvalue of A. It is possible for the multiplicity of λ as an eigenvalue of $A(i)$ to be greater than the multiplicity of λ as an eigenvalue of A. When this occurs, vertex i is called a Parter-vertex. A Parter-set is a set of Parter-vertices with the property that the multiplicity of λ continues to increase with each consecutive deletion of a row and column corresponding to a Parter-vertex in the set. This talk will present a result that identifies maximal Parter-sets for matrices whose graph is a tree. (Received August 18, 2014)

1106-05-331 **Ben Barber** and **Neil Hindman***, nhindman@aol.com, and **Imre Leader** and **Dona Strauss**. *Distinguishing subgroups of the rationals by their Ramsey properties.*

A system of linear equations with integer coefficients is *partition regular* over a subset S of the reals if, whenever $S \setminus \{0\}$ is finitely coloured, there is a solution to the system contained in one colour class. It has been known for some time that there is an infinite system of linear equations that is partition regular over $\mathbb{R}$ but not over $\mathbb{Q}$, and it was recently shown (answering a long-standing open question) that one can also distinguish $\mathbb{Q}$ from $\mathbb{Z}$ in this way. Our aim is to show that the transition from $\mathbb{Z}$ to $\mathbb{Q}$ is not sharp: there is an infinite chain of subgroups of $\mathbb{Q}$, each of which has a system that is partition regular over it but not over its predecessors. We actually prove something stronger: our main result is that if R and S are subrings of $\mathbb{Q}$ with R not contained in S, then there is a system that is partition regular over R but not over S. This implies, for example, that the chain above may be taken to be uncountable. (Received August 22, 2014)

1106-05-348 **Nicholas A. Loehr*** (nloehr@vt.edu), Virginia Tech Dept. of Mathematics, 460 McBryde Hall, Blacksburg, VA 24061-0123, and **Drew Armstrong** and **Gregory S. Warrington**. *Binomial coefficients, rational Catalan numbers, and their q-analogues.* Preliminary report.

Binomial coefficients count lattice paths contained in rectangles, whereas Catalan numbers (and their generalizations, the *rational* Catalan numbers) count lattice paths contained in certain triangles. The q-binomial coefficients enumerate lattice paths based on either their inversion count or their major index; these two combinatorial statistics lead to two distinct q-analogues of Catalan numbers. A long-standing open problem is to find a combinatorial statistic to explain the natural algebraic q-analogue of the rational Catalan numbers. We conjecture such a combinatorial statistic along with a novel combinatorial interpretation for the q-binomial coefficients. We give a bijective proof that the new formula for q-binomial coefficients implies the conjecture for q-Catalan numbers. (Received August 24, 2014)

1106-05-350 **Solomon Friedberg***, Department of Mathematics, Boston College, Chestnut Hill, MA 02467-3806, and **Lei Zhang**, Department of Mathematics, National University of Singapore, Block 17, 10 Lower Kent Ridge Road, 119076, Singapore. *Tokuyama-type formulas for characters of Spin groups.*

We obtain explicit formulas for the product of a deformed Weyl denominator with the character of an irreducible representation of the spin group $\mathrm{Spin}_{2r+1}(\mathbb{C})$, which is an analogue of the formulas of Tokuyama for Schur polynomials and Hamel-King for characters of symplectic groups. To give these, we start with a symplectic group and obtain such characters using the Casselman-Shalika formula. We then analyze this using objects which are naturally attached to the metaplectic double cover of an odd orthogonal group, which also has dual group $\mathrm{Spin}_{2r+1}(\mathbb{C})$. (Received August 24, 2014)

1106-05-370 **Michael Albert*** (michael.albert@cs.otago.ac.nz), **Bjarki Gudmundsson** (bjarkig12@ru.is) and **Henning Ulfarsson** (bjarkig12@ru.is). *Collatz meets Fibonacci.*

Neither Collatz nor Fibonacci really needs an introduction. Fibonacci's famous sequence is: $F_1 = F_2 = 1$ and $F_n = F_{n-1} + F_{n-2}$ for $n > 2$. The Collatz conjecture is that when the function

$$f(n) = \begin{cases} n/2 & \text{if } n \equiv 0 \pmod 2 \\ 3n+1 & \text{if } n \equiv 1 \pmod 2 \end{cases}$$

is applied iteratively to any initial value in $\mathbb{N}$, the values eventually reach a power of two. By considering the patterns arising in iterates of f just prior to the occurrence of a power of 2 we find a close encounter between Collatz and Fibonacci – but one which is followed by an interesting separation. (Received August 25, 2014)

1106-05-378 **Peter Lawson Maceli*** (plm2109@columbia.edu), **Maria Chudnovsky** and **Irena Penev**. *Excluding four-edge paths and their complements.*

Cographs and split graphs are two important subclasses of perfect graphs, both of which have nice characterizations in terms of excluding induced subgraphs. Cographs are obtained by excluding the three-edge path as an induced subgraph, while split graphs are characterized by excluding cycles of length four and five, and their complements. We consider the class of graphs which contain no induced four-edge path and no induced complement of a four-edge path. This class properly contains all cographs and all split graphs. We prove that a graph belongs to this class if and only if it can be obtained from split graphs and cycles of length five by repeated application of complementation, substitution, and "split graph unification." Split graph unification is a generalization of substitution which involves "gluing" two graphs along a common induced split graph. In this talk, we describe this new graph operation and give a structure theorem when excluding four-edge paths and their complements. (Received August 26, 2014)

1106-05-395 **Austin Mohr*** (amohr@nebrwesleyan.edu). *Checking Hats with the Lopsided Lovász Local Lemma.* Preliminary report.

The famous Hatcheck Problem imagines n men checking their hats at a restaurant and each receiving a randomly chosen hat after dinner. What is the probability that no man receives his own hat? We will explore a new proof that this probability tends to $\frac{1}{e}$ with n. The proof makes use of the lopsided Lovász local lemma and is striking for two reasons. First, there is a precise sense in which the original local lemma is wholly unsuited for the task, yet the seemingly mild generalization found in the lopsided version allows it to fully circumvent this difficulty. Second, the probabilistic content of the proof is readily transformed into a simple injection argument. The proof therefore demonstrates how one may wield a more powerful version of the local lemma through elementary means. (Received August 26, 2014)

1106-05-405 **Scott Andrews*** (scottdandrews@gmail.com) and **Nathaniel Thiem**. *Generalized Gelfand–Graev characters, Kostka polynomials, and supercharacters.*

The generalized Gelfand–Graev characters, originally constructed by Kawanaka, are useful tools in studying the representation theory of finite reductive groups. We calculate the multiplicities of the irreducible characters in the generalized Gelfand–Graev characters of $GL_n(\mathbb{F}_q)$. In doing so, we see connections to the ring of symmetric functions and the Kostka polynomials. We also describe these characters in terms of supercharacters of the unipotent upper-triangular matrices. (Received August 27, 2014)

1106-05-409 **Jennifer Morse** and **Anne Schilling*** (anne@math.ucdavis.edu), Department of Mathematics, One Shields Avenue, University of California, Davis, CA 95616. *k-charge and energy function.* Preliminary report.

We relate the energy function of Kirillov–Reshetikhin crystals to a statistic on bounded tableaux and in these terms, reformulate a generalized family of representatives for Schubert homology classes of the affine Grassmannian Gr. Along the way, a new description of the Pieri rule for $H_*(\mathrm{Gr})$ arises. (Received August 27, 2014)

1106-05-415 **Bridget Eileen Tenner*** (bridget@math.depaul.edu). *Frequency of factors in reduced words.*

We will look at reduced words of the longest element of the symmetric group. In these objects, chosen uniformly at random, we will compute the expected number of adjacent commuting symbols. These computations, together with a result of Reiner, will allow us to calculate the asymptotic frequencies of commutations, consecutive noncommuting pairs, and long braid moves. (Received August 27, 2014)

1106-05-418 **Madeline V Brandt*** (mbrandt@reed.edu). *Packing Polynomials on Sectors of $\mathbb{R}^2$.*

A polynomial $p(x, y)$ on a region S in the plane is called a packing polynomial if the restriction of $p(x, y)$ to $S \cap \mathbb{Z}^2$ yields a bijection to $\mathbb{N}$. In this talk, I discuss all quadratic packing polynomials on rational sectors of $\mathbb{R}^2$. (Received August 27, 2014)

1106-05-454 **Alex Strang*** (alex.g.strang@gmail.com), Department of Mathematics, Applied Mathematic, Case Western Reserve University, Cleveland, OH 44106, and **Oliver Haynes**, Golisano College of Computer and Information, Rochester Institute of Technology, Rochester, NY 14623. *Density Determined Graphs and Analyzing Cognitive Changesin the Brains of Athletes.*

Graph theoretic measures have emerged as valuable tools for analyzing social and biological networks. The distance between two nodes is defined to be number of edges in a shortest path between them. If there is no path between the two vertices, the distance is defined to be infinite. The average distance over all pairs of vertices is known as the characteristic path length. The average of the reciprocals of the distances is known as the global efficiency. In addition there are two local properties, clustering coefficients and local efficiency. While these four properties have been carefully studied, little has been determined as to how the two global properties relate to one another and how the two local properties relate to one another. We show that in both cases or most graphs we approach a linear relationship.

We then apply these findings in a real world setting involving the analysis of resting state functional MRI scans of football players at the University of Rochester. Our goal is to identify trends in the data that indicate decreased cognition in athletes resulting from repeated sub-concussive hits to the brain. (Received August 28, 2014)

1106-05-455 **Emily Gaub**, Department of Mathematics, 2043 College Way, Pacific University, Forest Grove, OR 97116, and **Michelle Rose*** (mmrose1@email.msmary.edu), Department of Math and Computer Science, 16300 Old Emmitsburg Road, Mount Saint Mary's University, Emmitsburg, MD 21727. *The Unit Bar Visibility Number of Graphs.*

A *t-unit-bar representation* of a graph G is an assignment t horizontal bars of equal length to each vertex of G so that two vertices u and v are adjacent if and only if an unobstructed vertical band of positive width joins a bar assigned to u to a bar assigned to v. The *unit bar visibility number* of G, denoted $ub(G)$, is the minimum t such that G has a t-unit-bar representation. In this talk we present a collection of results and bounds concerning the unit bar visibility number of graphs.Our results include a linear time algorithm for determining the unit bar visibility number of any tree and asymptotically sharp bounds for complete bipartite graphs. (Received August 28, 2014)

1106-05-456 **Kristen Bales*** (balesk@goldmail.etsu.edu), Department of Mathematics and Statistis, East Tennessee State University, Johnson City, TN 37614, and **Zachary Eager** (zde6919@rit.edu), School of Mathematical Sciences, Rochester Institute of Technology, Rochester, NY 14623. *Efficiency modularity for finding communities and anti-communities in networks.*

The increasing availability of large-scale data sets in the last decade has produced a tremendous amount of interest and progress in the field of network science. A community in a network is a group of nodes more tightly connected to each other than with nodes outside the group. Detecting community structure within networks is important in a variety of real-world settings, including social networks, metabolic networks, computer networks, and more. The modularity quality function commonly employed for finding community structure in complex networks is generalized in this work to a one-parameter family of quality functions. The generalization of network modularity discussed in this talk is based on the concept of graph efficiency, a metric first proposed by Latora and Marchiori. We define the *efficiency modularity* of a partition and demonstrate that it can be used to find either community or anti-community structure within a network. (Received August 28, 2014)

1106-05-468 **Shaun V. Ault*** (svault@valdosta.edu), Valdosta State University, 1500 N. Patterson St., Department of Math and Computer Science, Valdosta, GA 31698, and **Charles J. Kicey** (ckicey@valdosta.edu), Valdosta State University, 1500 N. Patterson St., Department of Math and Computer Science, Valdosta, GA 31698. *From signal processing to lattice paths.* Preliminary report.

In previous work, the authors explored a connection between a periodic version of Pascal's triangle and the sequences of corridor numbers arising from the lattice path literature. In turn, these observations naturally suggested discrete Fourier methods in order to further analyze the structures related to corridors. This leads to straightforward generalizations of certain formulas that previously had more technical proofs. We indicate how multidimensional Fourier methods can be used to analyze paths higher dimensional corridors. This presentation is based on work currently in preparation, as a follow-up to a recently accepted paper. (Received August 29, 2014)

1106-05-471 **Curtis G Nelson*** (cnelso42@uwyo.edu) and **Bryan L. Shader**. *A Checker-board Tiling Problem.*

Given nonnegative integral vectors $R = (r_1, r_2, \ldots, r_m)$ and $S = (s_1, s_2, \ldots, s_n)$, can a $m \times n$ checkerboard be tiled with vertical dimers (vertical 2×1 blocks) and monomers (1×1 blocks) so that there are exactly r_i dimers with the top half of the dimer in row i and s_j dimers in column j? This question can be thought of as an extension of the problem solved by the Gale-Ryser Theorem. We give an answer to this question in terms of R and S and discuss some other properties of this combinatorial object. (Received August 29, 2014)

1106-05-496 **Leslie Hogben*** (hogben@aimath.org). *Rectilinear crossing numbers of complete tripartite graphs.*

The *crossing number* of a graph G is the minimum number of crossings in a nondegenerate planar drawing of G. There has been extensive study of crossing numbers of complete bipartite graphs and complete graphs since Turán posed the question for the complete bipartite graph. Much less is known for complete tripartite graphs. A nondegenerate planar drawing of G is *rectilinear* if every edge is drawn as a straight line segment, and the *rectilinear crossing number* $\overline{\mathrm{cr}}(G)$ of G is the minimum number of crossings in a rectilinear drawing of G; clearly the rectilinear crossing number of G is an upper bound for the crossing number of G. Zarankiewicz proved that $\overline{\mathrm{cr}}(K_{m_1,m_2}) \le Z(m_1,m_2) := \left\lfloor \frac{m_1}{2} \right\rfloor \left\lfloor \frac{m_1-1}{2} \right\rfloor \left\lfloor \frac{m_2}{2} \right\rfloor \left\lfloor \frac{m_2-1}{2} \right\rfloor$ and attempted to prove $\overline{\mathrm{cr}}(K_{m_1,m_2}) = Z(m_1,m_2)$; the latter equality has become known as Zarankiewicz's Conjecture. We define an analogous bound for the complete tripartite graph and prove it is an upper bound for rectilinear crossing number of the complete tripartite graph. (Received August 30, 2014)

1106-05-545 **Luis David Garcia-Puente*** (lgarcia@shsu.edu), **Elizabeth Herman** (eaherman43@marianuniversity.edu), **Amadeus Martin** (amadeus06@gmail.com) and **Bryan Oakley** (boa1540@uga.edu). *Accessibility numbers in the sandpile monoid of a directed graph.* Preliminary report.

Let $\Gamma = (V, E)$ be a directed graph with a global sink s. A sandpile c is a vector of non-negative integers indexed by $V \setminus s$. Given a sandpile c, if $c(v) < \text{outdeg}(v)$, for all non-sink vertices v then c is stable; otherwise, c is unstable. In the latter case, c may be stabilized by a sequence of vertex topplings where an unstable vertex v topples sending a grain of sand through each of its out-edges. A stable sandpile c is accessible from a sandpile b if one can reach c from b by a series of sand additions and topplings. The accessibility number of a stable sandpile c is the number of stable sandpiles that access c. This leads to the *accessibility polynomial* of Γ

$$\mathcal{A}(x) = \sum_{i=1}^{m} a_i x^i,$$

where m is the number of stable sandpiles in Γ and a_i is the number of stable sandpiles with accessibility number i. The coefficient a_m is thus the number of sandpiles that are accessible by all other stable sandpiles. In this talk we introduce the accessibility polynomial and discuss some of its properties. For example, a_m equals the number of spanning trees of Γ directed to s. (Received September 02, 2014)

1106-05-552 **Andrew V Sills*** (asills@georgiasouthern.edu) and **Yuriy Choliy**. *A formula for the partition function that "counts".*

Let $p(n)$ denote the number of partitions of the integer n. The first exact formula for $p(n)$ was published by Hardy and Ramanujan in 1918. Two decades later, Hans Rademacher improved the Hardy–Ramanujan formula to give an infinite series that converges rapidly to $p(n)$.

In 2011, Ken Ono and Jan Bruinier surprised the world by announcing a new formula which attains $p(n)$ by summing a finite number of complex numbers which arise in connection with the multiset of algebraic numbers that are the union of Galois orbits for the discriminant $-24n+ 1$ ring class field.

Thus despite the fact that $p(n)$ is a combinatorial function, the known formulas for it are by no means "combinatorial" in the sense that they involve summing a finite or infinite number of complex numbers to obtain the correct (positive integer) value.

In this talk, I will present a formula for the partition function as a multisum each term of which actually counts a certain class of partitions. A comparison with a quasipolynomial representation will be given, as will as an associated polynomial approximation which appears to attain a level of accuracy comparable to that of the initial term of the Hardy–Ramanujan–Rademacher series. (Received September 02, 2014)

1106-05-555 **Alexander Woo** (awoo@uidaho.edu), **Benjamin Wyser** (bwyser@illinois.edu) and **Alexander Yong*** (ayong@uiuc.edu). *Combinatorics and geometry of symmetric orbit closures.* Preliminary report.

The geometry of symmetric orbit closures in the flag variety arises in the representation theory of the real forms of complex semisimple (reductive) Lie groups. In the case of the symmetric pairs (GL_n, K), Benjamin Wyser and the speaker have described analogues of the Schubert polynomials. I'll explain this work, as well as an ongoing project with Alexander Woo and Benjamin Wyser to understand the singularities of the orbit closures via combinatorics. (Received September 04, 2014)

1106-05-596 **Bert L Hartnell*** (bert.hartnell@smu.ca), Department of Mathematics & Computing Science, Saint Mary's University, Halifax, NovaScotia B3H 3C3, Canada, and **Jennie Newman**, Department of Mathematics & Computing Science, Saint Mary's University, Halifax, NovaScotia B3H 3C3, Canada. *Equi-b-matchable Graphs.*

Consider the following two player game. The players alternate choosing an edge in a graph. The only restriction is that at most b edges can be selected at any vertex. Which graphs have the property that the total number of edges selected is always the same regardless of how the players play? For instance, a star on $b+1$ or more vertices would always have exactly b edges chosen. The situation in which at most one edge (respectively, two edges) can be selected at any node and the outcome is always the same has been examined (such graphs are called *equi-matchable* (respectively, *equi-2-matchable*). In this note we characterize the equi-b-matchable graphs of girth 5 or more.

(Received September 03, 2014)

1106-05-600 **Art M Duval**, **Joshua Hallam*** (hallamjo@msu.edu), **Jeremy L Martin** and **Bruce E Sagan**. *Increasing Forests in Graphs and Simplicial Complexes.* Preliminary report.

Let G be a graph on a totally ordered vertex set labeled by $\{1, 2, \ldots, n\}$. We say a subtree of G is increasing if the vertices along any path starting at its minimum vertex increase in this ordering. Let f_k be the number of spanning forests of G with k edges such that each component is increasing. We show that the increasing spanning forest generating function,

$$IF(G,t) = \sum_{k=0}^{n-1} (-1)^k f_k t^{n-k}$$

always has nonnegative integer roots regardless of the ordering on the vertices. Moreover, we show that the increasing spanning forest generating function of G is equal to the chromatic polynomial of G if and only if the ordering on the vertex set is a perfect elimination ordering. We finish by discussing the generalization of these ideas to simplicial complexes. (Received September 03, 2014)

1106-05-615 **Ping Zhang*** (ping.zhang@wmich.edu), Departement of Mathematics, Western Michigan University, Kalamazoo, MI 49008. *Hamiltonian Extension.* Preliminary report.

The concepts of Hamiltonian paths, Hamiltonian cycles and Hamiltonian graphs have been studied extensively in the area of graph theory. The research in this area gave rise to a number of new concepts and properties involving paths and cycles in graphs, such as being Hamiltonian-connected, panconnected and pancyclic as well as the concept of path Hamiltonian graphs introduced in 2013. Inspired by these concepts, we introduce a related concept involving paths and cycles in graphs. Several results and open questions are presented in this area of research. (Received September 03, 2014)

1106-05-616 **Cristina M Ballantine*** (cballant@holycross.edu) and **Rosa C Orellana** (rosa.c.orellana@dartmouth.edu). *Schur-Positivity in a Square.*

Determining if a symmetric function is Schur-positive is a notoriously difficult problem. We study the Schur-positivity of a family of symmetric functions. Given a partition ν, we denote by ν^c its complement in a square partition (m^m). We conjecture a Schur-positivity criterion for symmetric functions of the form $s_{\mu'}s_{\mu^c} - s_{\nu'}s_{\nu^c}$, where ν is a partition of weight $|\mu| - 1$ contained in μ and the complement of μ is taken in the same square partition as the complement of ν. We prove the conjecture in many cases. (Received September 03, 2014)

1106-05-618 **Daniel Paul Johnston*** (daniel.p.johnston@wmich.edu), Departement of Mathematics, Western Michigan University, 1903 W. Michigan Ave., Kalamazoo, MI 49008. *Another Look at Ramsey Numbers.* Preliminary report.

In a red-blue coloring of a graph G, every edge of G is colored red or blue. For two graphs F and H, the Ramsey number $R(F, H)$ of F and H is the smallest positive integer n such that for every red-blue coloring of the complete graph K_n of order n, there is either a red subgraph isomorphic to F or a blue subgraph isomorphic to H. In the case where F and H are bipartite, the bipartite Ramsey number $BR(F, H)$ has been defined as the smallest positive integer r such that every red-blue coloring of the r-regular complete bipartite graph $K_{r,r}$ results in a red F or a blue H. We provide another look at these two well-known Ramsey numbers. Several results and open questions are presented in this area of research. (Received September 03, 2014)

1106-05-622 **Ira M. Gessel*** (gessel@brandeis.edu) and **Yan Zhuang**. *Counting permutations with even valleys and odd peaks.*

We find the exponential generating function for permutations with all valleys even and all peaks odd, answering a question posed by Liviu Nicolaescu. The generating function is

$$\left(1 - E_1 x + E_3 \frac{x^3}{3!} - E_4 \frac{x^4}{4!} + E_6 \frac{x^6}{6!} - E_7 \frac{x^7}{7!} + \cdots \right)^{-1}, \tag{1}$$

where $\sum_{n=0}^{\infty} E_n x^n/n! = \sec x + \tan x$, which resembles David and Barton's generating function

$$\left(1 - x + \frac{x^3}{3!} - \frac{x^4}{4!} + \frac{x^6}{6!} - \frac{x^7}{7!} + \cdots \right)^{-1}, \tag{2}$$

for permutations with no increasing runs of length 3 or more.

Following Dennis Chebikin, we define an alternating descent of a permutation to be an odd descent or an even ascent, and we define an alternating run to be a maximal consecutive subsequence with no alternating descents. Then the permutations we want to count are those with no alternating runs of length 3 or more.

Using noncommutative symmetric functions, we explain the similarity of (1) and (2) as a special case of a very general connection between generating functions for permutations by increasing runs and by alternating runs. (Received September 03, 2014)

1106-05-630 **Paula Egging** (eggi1576@ravens.benedictine.edu) and **Robert P Laudone*** (robert.laudone@gmail.com), 2 Sail View Court, Westerly, RI 02891, and **Amanda Owens** (asc003@connections.mcdaniel.edu). *Coloring Techniques for Pattern Avoidance over an Infinite Sequence.*

The authors make progress on the conjecture that one can construct an infinite square-free sequence from lists of size three. Furthermore, they extend the emerging method of entropy compression to prove that long-square-free sequences– sequences that avoids squares of length greater than four–can be chosen from lists of size three. Within this proof, the authors utilize and independently discover an isomorphism between plane trees and difference sequences (sequences of integers generated when running the algorithm in the entropy compression method).

This isomorphism reveals a deeply ingrained connection between the above conjecture and generating function theory, as generating functions are closely related to plane trees. With this in mind, the authors investigate Omega Sets in relation to generating functions. This exploration leads to the discovery of novel strategies that surpass the previous results of entropy compression in proving that one can avoid certain length squares over an infinite sequence when choosing from lists of varying sizes. The authors then proceeded to expand known work on shuffle squares to encompass shuffle long-squares, and provide a general formula for further expansion. (Received September 03, 2014)

1106-05-637 **Arthur T Benjamin*** (benjamin@hmc.edu), Department of Mathematics, Harvey Mudd College, 301 Platt Blvd, Claremont, CA 91711, and **Elizabeth Reiland**. *Combinatorial Proofs of Fibonomial Identities.* Preliminary report.

What do you get when you cross Fibonacci numbers with binomial coefficients? Fibonomial coefficients, of course! Fibonomials are defined like binomial coefficients, with integers replaced by their respective Fibonacci numbers. For example, $\binom{10}{3}_F = \frac{F_{10}F_9F_8}{F_3F_2F_1}$. Remarkably, $\binom{n}{k}_F$ is always an integer. In 2011, Bruce Sagan and Carla Savage derived two very nice combinatorial interpretations of Fibonomial coefficients in terms of tilings created by lattice paths. We believe that these interpretations should lead to combinatorial proofs of Fibonomial identities. We provide a list of simple looking identities that are still in need of combinatorial proof. (Received September 03, 2014)

1106-05-724 **David Amos*** (amosd2@math.tamu.edu), **Yair Caro**, **Randy Davila** and **Ryan Pepper**. *Upper bounds on the k-forcing number of a graph.*

Given a simple undirected graph G and a positive integer k, the k-forcing number of G, denoted $F_k(G)$, is the minimum number of vertices that need to be initially colored so that all vertices eventually become colored during the discrete dynamical process described by the following rule. Starting from an initial set of colored vertices and stopping when all vertices are colored: if a colored vertex has at most k non-colored neighbors, then each of its non-colored neighbors becomes colored. When $k = 1$, this is equivalent to the zero forcing number, a recently introduced invariant used to bound the maximum nullity of a graph. Here, we give several upper bounds for the k-forcing number. For example, we have for connected graphs $F_k(G) \leq \frac{(\Delta-2)n+2}{\Delta+k-2}$, where Δ is the maximum degree of G and n is the order of G. When $k = 1$, this gives a sharp answer to a question posed by Meyer about regular, connected, bipartite circulant graphs. Finally, we discuss a relationship between the k-forcing number and the connected k-domination number. (Received September 05, 2014)

1106-05-733 **Kara L Shavo*** (klshavo@presby.edu), Clinton, SC 29325, and **Heather Russell**, **Ruth Haas**, **Julie Beier**, **Janet Fierson** and **Carl Lienert**. *Induced Subgraphs of Coloring Graphs.*

This will be a continuation of Heather Russell's talk, "Classifying Coloring Graphs." For a simple graph G and a postive integer k, the k-coloring graph of G, denoted $\mathcal{C}_k(G)$, is the graph whose vertex set is the set of all proper k-colorings of the vertices of G, with two k-colorings adjacent if they differ in color on exactly one vertex of G. A graph H is called a *coloring graph* if there exists a graph G and a positive integer k such that $H = \mathcal{C}_k(G)$. We will focus on those graphs that cannot be induced subgraphs of coloring graphs, called *forbidden* subgraphs, and those that are induced subgraphs of coloring graphs, called *allowable* subgraphs. A forbidden subgraph is *minimal* if the removal of any vertex results in an allowable subgraph. Several useful lemmas for detecting forbidden subgraphs will be proved, as well as a technique for labeling vertices to identify allowable subgraphs. In addition to the cycle of length 5, several more minimal forbidden subgraphs of small order will be given, as well as an infinite class of minimal forbidden subgraphs. Thus, we will show that there exist an infinite number of minimal forbidden subgraphs. (Received September 05, 2014)

1106-05-740 **Dev R Phulara*** (phulara@comcast.net), 2400 Sixth Street, NW, Washington, DC 20059.
A Generalized Central Sets Theorem and Applications.

The central sets theorem originally proven by H. Furstenburg is a powerful result which is applicable to derive many combinatorial conclusions. Furstenburg's original theorem applied to N and finitely many sequences in Z. Some strengthenings of this theorem have been derived first by V. Bergelson and N. Hindman in 1990. Later in 2008, D. De, N. Hindman, and D. Strauss proved a stronger version of central sets theorem for arbitrary semigroups S which applied to all sequences in S. We provide here a generalization of the stronger version and some applications of this new generalization. (Received September 05, 2014)

1106-05-742 **Anne Schilling** (anne@math.ucdavis.edu), Department Of Mathematics, One Shields Ave, Davis, CA 95616, and **Travis Scrimshaw*** (tscrim@ucdavis.edu), Department of Mathematics, One Shields Ave, Davis, CA 95616. *Crystal structure for rigged configurations and the filling map.*

Rigged configurations are combinatorial objects which arise from statistical mechanics and Kerov, Kirillov and Reshetikhin gave a bijection between rigged configurations and semistandard tableaux in type $A_n^{(1)}$. Schilling has shown that there exists a classical crystal structure on rigged configurations in simply-laced affine type. In this setting the Kerov, Kirillov, Reshetikhin rigged configurations are highest weight elements. Conjecturally for general types, rigged configurations are in bijection with elements of tensor product of certain finite-dimensional affine crystals called Kirillov-Reshetikhin crystals (proven in certain cases). In this talk, I will present a classical crystal structure on rigged configurations for all affine types using virtual crystals. Furthermore I will present an extension of the so-called "filling map," introduced in recent work by Okado, Sakamoto, and Schilling for type $D_n^{(1)}$, to all non-exceptional affine types. (Received September 05, 2014)

1106-05-747 **Ralph P. Grimaldi*** (grimaldi@rose-hulman.edu), 5500 Wabash Ave, Terre haute, IN 47803. *Motzkin Paths with Exactly One Weak Ascent.*

For $n \geq 1$ we let a_n count the number of Motzkin paths from $(0,0)$ to $(n,0)$ with exactly one weak ascent. Such paths are made up of n steps, where each step is a U ($\nearrow$), an H ($\rightarrow$), or a D ($\searrow$), and they never fall below the x-axis. Each such path has exactly one weak ascent and ends in $k\,D$ steps, where $0 \leq k \leq \lfloor \frac{n}{2} \rfloor$. The initial $n-k$ steps comprise k U's and $n-2k$ H's. We find that $a_n = F_{n+1}$, where F_n denotes the n-th Fibonacci number.

The total numbers of U's, H's, and D's that appear among these a_n paths are determined, along with the numbers of consecutive pairs of the same type of step as well as different types of steps. In addition, the numbers of runs of consecutive identical steps are determined, and the number of isolated steps that appear among these a_n paths. Further results examine the sums of the locations of the different types of steps within the a_n paths. (Received September 05, 2014)

1106-05-753 **Yiguang Zhang*** (yzhan132@jhu.edu), Applied Mathematics & Statistics Department, Johns Hopkins University, Baltimore, MD 21218, and **Yonah Biers-Ariel**. *Superpatterns and Alon's Conjecture.* Preliminary report.

Given a set X and a class $\mathcal{R}$ such that each object in $\mathcal{R}$ is a string of k elements in X with certain restrictions, a *superpattern* is a string of n elements in X provided it contains at least one p-pattern for all $p \in \mathcal{R}$. We focus on three classes of superpatterns: superpatterns on words, superpatterns on preferential arrangements, and superpatterns on permutations and prove several structural results. For example, we show that the shortest superpattern that contains all the permutations of length k with entries from $[k]$ is also a superpattern of preferential arrangement with size k on the k characters. We then attempt to resolve an important conjecture of Noga Alon on the length of the smallest randomly generated permutation that contains patterns of all permutations at length k with high probability, where $k < n$. (Received September 05, 2014)

1106-05-779 **Anant Godbole**, **Elizabeth Kelley*** (ekelley@g.hmc.edu), **Emily Kurtz** and **Yiguang Zhang**. *The Total Acquisition Number of the Randomly Weighted Path.*

There exists a significant body of work on determining the acquisition number of various graphs when the vertices of those graphs are each initially assigned a unit weight. We determine the acquisition number of the path, star, complete, complete bipartite, cycle, and wheel graphs for variations on this initial weighting scheme, with the majority of our work focusing on the acquisition number of randomly weighted graphs. In particular, we bound the expected acquisition number of the n-path when n "units" of integral weight, or chips, are randomly distributed across its vertices between 0.26n and 0.37n. We then use Azuma's Lemma to prove that this expected value is tightly concentrated. Additionally, we offer a non-optimal acquisition protocol algorithm for the randomly weighted path and compute the expected size of the resultant residual set. (Received September 06, 2014)

1106-05-785 **Aaron Landesman*** (aaronlandesman@college.harvard.edu). *Stasinski and Voll's Hyperoctahedral Group Conjecture.*

In a recent paper, Stasinski and Voll introduced a length-like statistic on hyperoctahedral groups and conjectured a product formula for this statistic's signed distribution over arbitrary descent classes. Stasinski and Voll proved this conjecture for a few special types of parabolic quotients. We prove this conjecture in full, showing it holds for all parabolic quotients. In the case that the descent class is a singleton, this formula gives the Poincaré polynomials for the varieties of symmetric matrices of a fixed rank. (Received September 06, 2014)

1106-05-786 **Hailee Peck*** (hpeck@millikin.edu), **David Hemminger** (david.hemminger@duke.edu), **Jacob Haley** (jhaley3@nd.edu) and **Aaron Landesman** (aaronlandesdman@gmail.com). *Artin Group Presentations Arising from Cluster Algebras.*

In 2003, Fomin and Zelevinsky proved that finite type cluster algebras can be classified by Dynkin diagrams. Then in 2013, Barot and Marsh defined the presentation of a reflection group associated to a Dynkin diagram in terms of an edge-weighted, oriented graph, and proved that this group is invariant (up to isomorphism) under diagram mutations. In this paper, we extend Barot and Marsh's results to Artin group presentations, defining new generator relations and showing mutation-invariance for these presentations. (Received September 06, 2014)

1106-05-793 **Endre Csoka**, **Gabor Lippner*** (g.lippner@neu.edu) and **Oleg Pikhurko**. *Measurable edge coloring.* Preliminary report.

The classical theorem of Vizing states that every graph of maximum degree d admits an edge-coloring with at most $d+1$ colors. Furthermore, as it was earlier shown by Kőnig, d colors suffice if the graph is bipartite.

We investigate the existence of measurable edge-colorings for graphings. A graphing is an analytic generalization of a bounded-degree graph that appears in various areas, such as sparse graph limits and orbit equivalence theory. We show that every graphing of maximum degree d admits a measurable edge-coloring with $d + O(\sqrt{d})$ colors; furthermore, if the graphing has no odd cycles, then $d+1$ colors suffice. In fact, if a certain conjecture about finite graphs that strengthens Vizing's theorem is true, then our method will show that $d+1$ colors are always enough. (Received September 06, 2014)

1106-05-794 **Jonathan DeWitt*** (jdewitt@haverford.edu). *Longest Increasing Subsequences of Multiset Permutations.*

The expected length of the longest increasing subsequence of a random permutation has been well studied. We generalize this problem to the case of a random permutation of a multiset consisting of k copies of the numbers 1 through n. We give a soft argument to show that this limit exists and is $\Theta(\sqrt{n})$ in the case of strictly increasing subsequences. We show that in the case of two copies of each letter the expected length of either the longest strictly increasing subsequence or the longest weakly increasing subsequence is $2\sqrt{2}\sqrt{n}$. We then show how this problem can be further generalized in terms of the height of a poset intersected with a random linear order. (Received September 06, 2014)

1106-05-828 **Noureen Khan***, 7300 University Hills Blvd, Dallas, TX 75241. *On Warping Degree of Virtual Links.*

For virtual links, warping degree represents such a complexity of link diagram and depends on its orientation. Previously, we defined the invariants of warping degree for virtual knot diagrams, here we extend the notion for virtual link diagrams. We show that a virtual link diagram D of n-component, the sum of warping degrees of D and its inverse diagram, $-D$, we have $W(D)+W(-D) \leq C(D)$, where $C(D)$ is the total number of crossings of D. Further, the equality holds if and only if D is a balanced link diagram. (Received September 07, 2014)

1106-05-837 **Ralph Morrison** and **Ngoc Mai Tran*** (tran.mai.ngoc@gmail.com). *Commuting tropical variety.*

Tropical matrices are closely tied with shortest paths in a directed graph, as well as polytropes - polytopes which are both ordinarily and tropically convex. They are not yet well-understood. In this introductory talk, we look for necessary and sufficient conditions for two square tropical matrices to commute. I will outline some recent results, and pose some open questions on the combinatorics of the tropical variety of commuting matrices. No tropical knowledge is required.

Joint work with Ralph Morrison (UC Berkeley) (Received September 07, 2014)

1106-05-842 **Yonah Biers-Ariel*** (biersay@whitman.edu) and **Elizabeth Kelley**. *Packing Sequences Into Words.*

If we consider a word of length n on the alphabet $\{0, 1\}$, we can find the number of distinct subsequences contained in that word. It is already known that the expected number of distinct subsequences is asymptotically 1.5^n when each letter takes on the value 1 with probability .5. We allow each letter to take on the value 1 with probability α, and find the expected number of distinct subsequences in this more general case.

We attempt to further generalize this to words generated by Markov chains, and obtain partial results in this case. (Received September 10, 2014)

1106-05-843 **Anna Puskás*** (puskas@ualberta.ca). *Highest-weight crystals, Demazure-Lusztig operators and Metaplectic Whittaker functions.*

Two separate approaches to the construction of p-adic metaplectic Whittaker functions can be described in the language of combinatorial representation theory. One approach, due to Chinta and Offen for GL_r and to McNamara in general, represents the spherical Whittaker function in terms of a sum over a Weyl group. The second approach, by Brubaker, Bump and Friedberg and separately by McNamara, expresses it as a sum over a highest weight crystal. In the special case of the non-metaplectic spherical function, these constructions are linked by Tokuyama's theorem. Further, in the non-metaplectic case, work of Brubaker, Bump and Licata describes Iwahori-Whittaker functions using Demazure-Lusztig operators.

In this talk, we present a generalization of Tokuyama's theorem. The result links the two constructions of the metaplectic spherical Whittaker function using only combinatorial methods. In addition, it presents a way of recovering the construction of certain Iwahori-Whittaker functions as a sum over a Demazure-crystal. The main tools involved are metaplectic Demazure and Demazure-Lusztig operators, introduced in joint work with Gautam Chinta and Paul E. Gunnells. (Received September 07, 2014)

1106-05-850 **Andrew T. Wilson*** (atwilson@ucsd.edu). *Parking functions with undesirable spaces.* Preliminary report.

A recent conjecture of Haglund relates an operator from the theory of diagonal harmonics to a new class of decorated parking functions. These decorated parking functions can be described in terms of a parking lot where some spaces are undesirable. We will explore the combinatorics of these objects as well as their relationship to recent extensions of Mahonian statistics to ordered set partitions. (Received September 08, 2014)

1106-05-855 **Nursel Erey***, Department of Mathematics and Statistics, Dalhousie University, Halifax, NS B3H 4R2, Canada, and **Sara Faridi**. *Betti Numbers of Simplicial Forests.* Preliminary report.

Given a simplicial complex one can associate the facet ideal which is generated by the monomials corresponding to the facets of the simplicial complex. The relation between the algebraic invariants of the facet ideal and the combinatorial properties of the corresponding simplicial complex has received considerable amount of interest. In this talk, we will focus on a class of simplicial complexes, namely simplicial forests. We will combinatorially characterize the Betti number for the facet ideal of a simplicial forest. This generalizes the previously known characterization of the Betti number for the edge ideal of a graph forest. (Received September 08, 2014)

1106-05-857 **J. Beier**, **J. Fierson**, **R. Haas**, **C. Lienert**, **Heather M. Russell*** (hrussell2@washcoll.edu) and **K. Shavo**. *Classifying coloring graphs.*

Given a graph G and a natural number k, the k-coloring graph of G is the graph whose vertex set is the proper k-colorings of the vertices of G with two k-colorings adjacent if they differ on exactly one vertex. In this talk, we ask the question: What graphs can be coloring graphs? In other words, given a graph H, do there exist G and k such that H is the k-coloring graph of G? We will answer this question for several classes of graphs and discuss important obstructions to being a coloring graph involving order, girth, and induced subgraphs.

This is joint work with J. Beier, J. Fierson, R. Haas, C. Lienert, and K. Shavo begun in 2013 at the summer REUF workshop. K. Shavo will give a second talk about this project with a focus on forbidden subgraphs. (Received September 08, 2014)

1106-05-859 **Cayla D McBee*** (cmcbee@providence.edu), Department of Mathematics and CS, 1 Cunningham Square, Providence, RI 02918. *Prime Graph Labelings.*

A graph G on v vertices has a prime labeling if and only if there exists a labeling of the vertices with the numbers 1 through v such that any two adjacent vertices have labels which are relatively prime. Determining which graphs have prime labelings is an interesting and accessible problem for collaboration with undergraduate students. I will discuss the prime labeling problem focussing on my recent work with students involving the prime labeling of hypercubes, Q_k, and grid graphs, $P_m \times P_n$. (Received September 08, 2014)

1106-05-871 **Sergi Elizalde** and **Megan Martinez*** (megan.a.martinez.gr@dartmouth.edu). *Patterns in Random Walks.*

In this talk, we explore patterns in random walks in discrete time on the real number line. In such a random walk, we choose $n-1$ i.i.d. random variables that serve as the steps of the walk, $X_1, X_2, \ldots, X_{n-1}$. The walk is then the series $Z_0, Z_1, \ldots, Z_{n-1}$ where $Z_0 = 0$ and $Z_k = \sum_{i=1}^{k} X_i$. A set of n consecutive values in a random walk is associated to a permutation in S_n using relative ordering. With this setup, it is easy to see that not all patterns occur with equal probability; however, there are some instances where two patterns occur with equal probability given any probability distribution. A permutation and its reverse-complement will always have the same probability of occurring, but this is not the only case. The permutations 612435 and 354612 form a nontrivial example of this phenomenon.

We are interested in permutations $\pi, \tau \in S_n$ such that the probability π occurs in a random walk is equal to the probability τ occurs in a walk, regardless of the probability distribution of the steps. Our goal is to completely characterize the classes of permutations with equal probabilities. (Received September 08, 2014)

1106-05-880 **Mary K Flagg*** (flaggm@stthom.edu). *Power Graphs of Finite Associative Rings.*

The directed power graph of a semigroup S is the graph with vertices the elements of S and an arc $a \to b$ if $a \neq b$ and $b = a^n$ for some positive integer n. Power graphs have been studied in the categories of finite semigroups and finite groups. Extending this construction to the category of finite associative rings, consider how the power graphs of the multiplicative semigroup and additive abelian group of a ring are connected to its algebraic properties. It is well known that a finite ring is the ring direct sum of rings of prime power order. Therefore, the investigation has two directions, rings of order p^n for some prime p and positive integer n and direct sums of rings with different prime power orders. Results include the fact that a ring of square-free order is determined by the structure of its multiplicative power graph. (Received September 08, 2014)

1106-05-889 **Cristian Lenart*** (clenart@albany.edu), Department of Mathematics and Statistics, State University of New York at Albany, 1400 Washington Avenue, Albany, NY 12222, and **Arthur Lubovsky** (alubovsky@albany.edu), Department of Mathematics and Statistics, State University of New York at Albany, 1400 Washington Avenue, Albany, NY 12222. *On the alcove model for Kirillov-Reshetikhin crystals.*

Kirillov-Reshetikhin (KR) crystals are colored directed graphs encoding the structure of certain finite-dimensional representations of affine Lie algebras. In recent joint work S. Naito, D. Sagaki, A. Schilling, and M. Shimozono, I gave a uniform realization of a tensor product of (column shape) KR crystals, for all untwisted affine types, in terms of the so-called quantum alcove model. I will present new results related to this model: its independence from an initial choice (of a chain of roots), and an application to a uniform realization of the combinatorial R-matrix (i.e., the unique affine crystal isomorphism permuting factors in a tensor product of KR crystals). (Received September 08, 2014)

1106-05-891 **Lara Pudwell*** (lara.pudwell@valpo.edu), Department of Mathematics and Statistics, 1900 Chapel Drive, Valparaiso, IN 46383. *Pattern-avoiding ascent sequences.*

Let $\mathrm{asc}(x_1 \cdots x_n)$ be the number of ascents in $x_1 \cdots x_n$. An *ascent sequence* $x_1 \cdots x_n$ is a sequence of nonnegative integers such that $x_1 = 0$, and for $1 < i \leq n$, $x_i \leq \mathrm{asc}(x_1 \cdots x_{i-1}) + 1$. In this talk, we consider ascent sequences avoiding various patterns of length 3 or length 4. Of particular note, we show that 0021-avoiding ascent sequences are counted by the binomial convolution of the Catalan numbers. This result, together with previous work of Duncan, Steingrímsson, Mansour, and Shattuck, completes the Wilf classification of single patterns of length 4 for ascent sequences. (Received September 08, 2014)

1106-05-915 **Andrew J Wills*** (awillsa@vt.edu). *A combinatorial interpretation for Hall-Littlewood polynomials.* Preliminary report.

We introduce a combinatorial model for Hall-Littlewood polynomials, a class of symmetric polynomials in N variables, using objects called abacus-tournaments. Individual abacus-tournaments are given signed weights and summing the signed weights of certain abacus-tournaments gives the Hall-Littlewood polynomial. Combinatorial proofs of identities for Hall-Littlewood polynomials, like the first Pieri rule, can be simple and elegant in place of traditional algebraic methods. (Received September 08, 2014)

1106-05-918 **Sergey Kitaev** (sergey.kitaev@cis.strath.ac.uk), Dept. of Computer and Information Science, University of Strathclyde, Glasgow, United Kingdom, **Miles Jones** (mjones@inst-math.utalca.cl), Instituto de Mathemática, Unversidad de Talca, Camino Lircay, Chile, and **Jeffrey B. Remmel*** (jremmel@ucsd.edu), Department of Mathematics, University of California, San Diego, La Jolla, CA 92093-0112. *μ patterns in n-cycles.*

Given an n-cycle C in the symmetric group S_n, we say that a pair $\langle i, j\rangle$ matches the μ pattern if $i < j$ and, as we traverse around C in a clockwise direction starting at i and ending at j, we never encounter a k with $i < k < j$. We say that a μ-match $\langle i, j\rangle$ in C is trivial if $j = i + 1$ and is non-trivial otherwise. We say that an n-cycle C in S_n is incontractible if there is no i which is immediately followed by $i + 1$ as we traverse in a clockwise direction around C. We show that the generating function $NTI_{n,\mu}(q)$ of q raised to the number of nontrivial μ-matches in C over all incontractible n-cycles C in S_n is a new q-analogue of the derangement numbers. We also show that there is a surprising connection between the charge statistic of Lascoux and Schüzenberger and the polynomials $NTI_{n,\mu}(q)$ in that the coefficient of the smallest power of q in $NTI_{2k+1,\mu}(q)$ is the number of permutations in S_{2k+1} whose charge path is a Dyck path. (Received September 08, 2014)

1106-05-962 **Edward Richmond*** (edward.richmond@okstate.edu) and **William Slofstra**. *Fiber bundle structures on Schubert varieties.* Preliminary report.

We give a combinatorial characterization of when fiber-bundle structures on Schubert varieties are induced from the natural projection maps between the flag varieties. Applications of such fiber-bundle structures include a new proof of Peterson's theorem that rationally smooth Schubert varieties are smooth and a proof of the Billey-Crites conjecture that a Schubert variety in affine type A is smooth if and only if the corresponding affine permutation avoids the patterns 4231 and 3412. (Received September 09, 2014)

1106-05-969 **Miklos Bona*** (bona@ufl.edu). *A new record in 1324-avoiding permutations.*

Eliminating some waste in an earlier method, we prove that the number of 1324-avoiding permutations of length n is less than 13.74^n. (Received September 09, 2014)

1106-05-972 **Brendan Pawlowski*** (salmiak@math.washington.edu) and **Sara Billey**. *Permutation patterns and Stanley symmetric functions.*

Given a permutation w, Stanley defined a symmetric function F_w which encodes information about the reduced words of w, and showed that F_w is a single Schur function exactly when w avoids the pattern 2143. We generalize this statement, showing that the Schur expansion of F_w respects pattern containment in a certain sense, and that the number of Schur function terms is determined by pattern avoidance conditions on w. Our proofs use the *diagram Specht modules* introduced by James and Peel, which in this case are closely related to the Schubert modules of Kraśkiewicz and Pragacz. (Received September 09, 2014)

1106-05-982 **Michael Albert**, **Anders Claesson**, **Bjarki Gudmundsson** and **Henning Ulfarsson*** (henningu@ru.is), Reykjavik University, School of Computer Science, Menntavegi 1, 101 Reykjavik, Iceland. *Struct: An algorithm for guessing the structure and enumeration of permutation sets.* Preliminary report.

Struct is an algorithm being developed by the authors to guess the structure of a set of permutations. In some cases the structure discovered is sufficient to infer the generating function of the set and provides an enumeration of the permutations by length. A preliminary version of the algorithm will be presented and applied to several sets of permutations. Future enhancements of the algorithm will be able to conjecture upper and lower bounds where exact enumeration is still out of reach (for a computer algorithm). This research is funded by the Icelandic Research Fund, Grant no. 141761-051 (Received September 09, 2014)

1106-05-983 **Janine LoBue Tiefenbruck*** (jlobue@ucsd.edu) and **Jeffrey B. Remmel**. *Simple Frame Patterns in Words.* Preliminary report.

A mesh pattern is a particular type of permutation pattern introduced by Brändén and Claesson [Mesh patterns and the expansion of permutation statistics as sums of permutation patterns, *Elect. J. Comb.*, **18(2)** (2011), #P5, 14pp.] A particular class of mesh patterns is boxed patterns, later called frame patterns, introduced by Avgustinovich, Kitaev, and Valyuzhenich [Avoidance of boxed mesh patterns on permutations, *Discrete Appl. Math.*, **161** (2013) 43–51.] Simple frame patterns have been studied in several contexts. Avgustinovich, Kitaev, and Valyuzhenich first studied the avoidance of many frame patterns in permutations and in certain pattern-avoiding classes of permutations. Jones, Kitaev, and Remmel studied the distribution of frame 12-matches and frame 21-matches in the cycle structure of permutations [Frame patterns in n-cycles, preprint.] In this talk, we will survey some recent results on simple frame patterns in words. (Received September 09, 2014)

1106-05-988 **Vincent Coll** and **Alexander Halperin*** (adhalperin@salisbury.edu), Dept. of Mathematics and Computer Science, 1101 Camden Ave., Salisbury, MD 21801, and **Colton Magnant** and **Pouria Salehi**. *Enomoto and Ota's Conjecture Holds for Large Graphs.* Preliminary report.

In 2000, Enomoto and Ota conjectured that if a graph G satisfies $\sigma_2(G) \geq n+k-1$, then for any set of k vertices $v_1, \ldots, v_k$ and for any positive integers $n_1, \ldots, n_k$ with $\sum n_i = |G|$, there exists a partition of $V(G)$ into k paths $P_1, \ldots, P_k$ such that v_i is an end of P_i and $|P_i| = n_i$ for all i. We prove this conjecture when $|G|$ is large. Our proof uses the Regularity Lemma along with several extremal lemmas, concluding with an absorbing argument to retrieve misbehaving vertices. (Received September 09, 2014)

1106-05-996 **Gabriel Feinberg*** (gfeinberg@haverford.edu) and **Kyu-Hwan Lee**. *Homogeneous Representations of Khovanov-Lauda-Rouquier Algebras.*

The Khovonov-Lauda-Rouquier (KLR) algebra arose out of attempts to categorify quantum groups. Kleshchev and Ram proved a result reducing the representation theory of these algebras to the study of irreducible cuspidal representations. In finite types, these cuspidal representations are part of a larger class of homogeneous representations, which are related to fully commutative elements of Coxeter groups.

For KLR algebras of types A_n and D_n, we classify and enumerate these homogeneous representations. (Received September 09, 2014)

1106-05-1006 **M Just** and **H Wang***, hwang@georgiasouthern.edu. *Permutations containing large number of a prescribed pattern.* Preliminary report.

We examine permutations that has the largest number of a particular pattern. Some characteristics of such permutations and bounds on the number of patterns will be presented. This is joint work with Matthew Just. (Received September 09, 2014)

1106-05-1007 **Bertilla Sieben*** (bsieben@princeton.edu). *Universal Cycles of Partitions.* Preliminary report.

In this talk, we will first show that the ratio $\frac{S_d(n,k)}{S(n,k)} \to 1$ (the ratio of the number of partitions of a set of n elements into k subsets of distinct sizes over the total number of partitions of a set of n elements into k subsets goes to 1) as $n \to \infty$ and k is fixed. We will then show that there exist universal cycles of partitions of sets of n elements into k subsets of distinct sizes when k is sufficiently smaller than n, and therefore that there exist U-packings of partitions of sets of size n into k subsets. (Received September 16, 2014)

1106-05-1028 **Daniela Ferrero*** (dferrero@txstate.edu), 601 University Drive, Department of Mathematics, Texas State University, San Marcos, TX 78666. *On the power domination problem in graphs.*

Electric power companies need to monitor the state of their networks continually in order to prevent black-outs. One method to accomplish this task is to place Phase Measurement Units (PMUs) at selected network locations. The synchronized readings provided by these PMUs, in conjunction with Kirchoff's laws, permit to determine the state of the power network at any element of the network. Because of the high cost of a PMU, it is important to minimize the number of PMUs while maintaining the ability of monitoring the entire system. Since power networks can be modeled by graphs, this problem translates into a graph theory problem: the power domination problem. The power domination problem in graph theory is closely related the zero-forcing problem in algebraic graph theory and it is also related to some chip-firing games. In this talk we will survey known results and future challenges in the study of the power domination problem, especially in connection to other combinatorial and geometrical problems. (Received September 09, 2014)

1106-05-1031 **Emily Kurtz*** (ekurtz@wellesley.edu) and **Fan Yang** (fanyang1@andrew.cmu.edu). *Gray Code Distance 2 Graphs.* Preliminary report.

Past research in the area of Gray codes has focused extensively on using this code to label vertices of graphs and to discover characteristics of these graphs. We continue in this direction but deviate slightly by creating edges between vertices which are not of Gray code distance 1 from each other, but instead of some other set integer distance. We then find characteristics of these new graphs. The majority of our results focus on distance 2 graphs, with some results for general distances. Our biggest result is on the structure of the graphs for any distance. We find that two isomorphic components result when the distance is even, as long as the distance is strictly larger than the string length, and that the graph will have only one component if the distance is odd and strictly greater than the string length. Other areas explored include the chromatic number, cliques, Hamiltonicity, and perfect matchings of the graphs. (Received September 09, 2014)

1106-05-1034 **Christopher Coscia*** (cosciach@bc.edu) and **Jonathan DeWitt**. *Locally Convex Words and Permutations.*

Define a *k-convex permutation* $\pi : [n] \to [n]$ to be a bijection obeying the condition $2\pi(i) \geq \pi(i-1)+\pi(i+1)-k$ for all $i \in \{2, 3, \ldots, n-1\}$ for fixed $k \geq 0$, and denote the number of k-convex permutations of length n by $f_k(n)$. We attempt to determine $f_k(n)$ for $k = 0, 1$, and 2, cases under which these permutations satisfy nice properties; in particular, they are consecutive 213 and 312 avoiding. We show that $f_0(n)$ is precisely 8 for $n > 4$ and demonstrate, for $k = 1, 2$, a method of exhaustively constructing k-convex permutations. We contruct an infinite "descendant digraph" for $k = 1$ and $k = 2$, and use the transfer matrix method with generating functions to determine $f_1(n)$, give a partial solution for $f_2(n)$, and demonstrate that it is possible to give arbitrarily tight exponential bounds in both cases.

Similarly, we define *k-convex words on a p-alphabet* to be functions $g : [n] \to [p]$ satisfying $2g(i) \geq g(i-1) + g(i+1) - k$ for all $i \in \{2, 3, \ldots, n-1\}$. We demonstrate that it is possible to find a generating function $G_{p,k}$ for any values of p, k, and show that the number of 0-convex words is eventually constant in n for any p, giving an expression for this constant in p related to the integer partition numbers. (Received September 09, 2014)

1106-05-1035 **Holley Friedlander*** (friedlah@dickinson.edu), **Louis Gaudet** and **Paul E. Gunnells**. *A Tokuyama-type formula for G_2.*

In 1988 Tokuyama used Gelfand-Tsetlin patterns to prove a deformation of the Weyl character formula for GL_n. In this talk, we conjecture an analogous formula for the root system G_2. As evidence for our conjecture, we prove a combinatorial version of the Gindikin–Karpelevič formula for G_2, in the spirit of Bump-Nakasuji's formula for type A. (Received September 09, 2014)

1106-05-1036 **Samuel Zbarsky*** (sa_zbarsky@yahoo.com). *Unimodality of Partitions in Near-Rectangular Ferrers Diagrams.*

We look at the rank generating function G_λ of partitions inside the Ferrers diagram of some partition λ, investigated by Stanton in 1990, as well as a closely related problem investigated by Stanley and Zanello in 2013. We show that G_λ is not unimodal for a larger class of 4-part partitions than previously known, and also that if the ratios of parts of λ are close enough to 1 (depending on how many parts λ has), or if the first part is at least half the size of λ, then G_λ is unimodal. (Received September 09, 2014)

1106-05-1101 **Andrew R Gainer-Dewar*** (gainerdewar@hws.edu), HWSC Dept. of Math and CS, 300 Pulteney Avenue, Geneva, NY 14456. *Species with an equivariant group action.*

We present the theory of Γ-species, which extends Joyal's theory of combinatorial species to incorporate information about "structural" (i.e. relabeling-invariant) group actions, and illustrate how it extends the major algebraic operations on species including $+$, $\cdot$, $\circ$ (plethystic composition), and $\square$ (functorial composition). We present an analogue of the Pólya-Redfield Enumeration Theorem which allows counting of "partially-labeled" or colored structures, including quotient structures. We then present some applications of the theory to graph enumeration, including some useful building blocks and some more complex classes of graphs. (Received September 10, 2014)

1106-05-1123 **Jonathan Bloom*** (jbloom314@gmail.com) and **Alex Burstein**. *Another (more refined) look at the Wilf-equivlance of certain length 4 pattern.*

In their recent paper *Mahonian Pairs*, Sagan and Savage propose studying the following q-analogue of Wilf-equivalence. Let $f : S_n \to \{0, 1, 2, \ldots\}$ be any permutation statistic and define the generating function

$$F_\sigma = \sum_{\pi \in AV(\sigma)} z^{|\pi|} q^{f(\pi)}.$$

We then say that σ is *f-Wilf-equivalent* to τ provided $F_\sigma = F_\tau$. Motivated by this definition Dokos et al. provided the first in-depth study of maj-Wilf-equivalence and inv-Wilf-equivalence. In their paper, they conjectured that 1423 and 2413 are maj-Wilf-equivalent. We will provide a bijective proof of this fact and show that, in fact, the following list of statistics are simultaneously equidistributed between these two sets: position of descents, right-to-left maxima, −bonds.

On a related note, Egge in 2011 conjectured that

$$|AV_n(2143, 3142, \tau)| = (n-1)\text{st large Schröder number}$$

where $\tau \in \{24613, 254613, 263514, 524361, 546132\}$. Using simple permutations and generating function techniques, we provide proofs of all these cases. Lastly, we will discuss some conjectures involving permutation statistics that generalize Egge's observation. (Received September 10, 2014)

1106-05-1139 **Chris Coscia** (cosciach@bc.edu), **Jon DeWitt** (jdewitt@haverford.edu), **Fan Yang*** (fanyang1@andrew.cmu.edu) and **Yiguang Zhang** (yzhan132@jhu.edu). *Online Dominating Set.*

We consider a greedy online algorithm that finds a dominating set of a graph. This algorithm is online because vertices of the graph are revealed one by one. From a practical perspective, this algorithm is easy to implement and can be applied to graphs that are not fully known.

We analyze the performance of this algorithm and study how graph operations affect the performance. There are two main results:

1) We calculated expected dominating set sizes of paths, cycles, stars, multi-stars and bipartite graphs using this algorithm.

2) We found examples where adding edges to the graphs actually increases their expected dominating set sizes.

Because of its simplicity, this online algorithm can also be used to find chromatic numbers of graphs and etc. We hope our analysis of the algorithm can inspire more applications in the future. (Received September 11, 2014)

1106-05-1167 **Ibrahim A Saleh*** (ibrahim.saleh@uwc.edu), Ibrahim Saleh, 518 S 7th Ave, Wausau, WI 54401. *Representations of generalized Weyl algebras arising from non-commutative cluster structures.*

In this talk we will introduce a class of non-commutative algebras that carry a cluster-like structure. These algebras are related to generalized Weyl algebras. The space of all cluster monomials gives rise to a combinatorial data which will be used to construct an indecomposable and irreducible representations of the associated generalized Weyl algebras. (Received September 11, 2014)

1106-05-1185 **Linda L Eroh*** (eroh@uwosh.edu), **Cong X Kang** and **Eunjeong Yi**. *A Comparison between the metric dimension and zero-forcing number of trees and unicyclic graphs.*

We say that a set of vertices $W \subseteq V(G)$ is a *resolving set* for G if it has the property that for every pair of distinct vertices $x, y \in V(G)$, there is a vertex $w \in W$ such that $d(x, w) \neq d(y, w)$. The *metric dimension* of G, $dim(G)$, is the minimum number of vertices in a resolving set for G. To define the zero-forcing number, we consider a graph with each vertex colored either blue or red. The color-change rule says that a red vertex is recolored blue if it is the only red neighbor of some blue vertex. Then the *zero-forcing number* $Z(G)$ of a graph G is the minimum number of vertices which must be colored blue initially so that, after a finite number of iterations of the rule, every vertex is colored blue. We show that $dim(T) \leq Z(T)$ for every tree T. For every tree T and edge $e \in E(\overline{T})$, we show $dim(T) - 2 \leq dim(T + e) \leq dim(T) + 1$. For any unicyclic graph G, we show $dim(G) \leq Z(G) + 1$. (Received September 11, 2014)

1106-05-1216 **Mary Radcliffe*** (radcliffe@math.washington.edu). *Nonlinear eigenvalues of graphs.*

Abstract: From a geometrical perspective, one can view the first eigenvalue of graph as a measure of the distortion obtained when embedding a graph into $\mathbb{R}$. This measurement can be generalized by embedding the graph into an arbitrary metric space X. We here discuss some structural results using this nonlinear eigenvalue generalization when X is itself a graph. (Received September 11, 2014)

1106-05-1309 **Alison M Marr*** (marra@southwestern.edu). *Some recent results on magic-type labelings of directed graphs.*

This talk will focus on three types of magic labelings for directed graphs. We will discuss recent results related to magic labelings, vertex-magic edge labelings, and in-magic labelings of directed graphs. Each of these definitions is slightly different, but the main idea is that the sum of labels going into and/or out of a vertex will be constant across all vertices. Examples will be given and future questions will be posed. Much of this work is in collaboration with undergraduate students and thus this talk is accessible to undergraduates. Collaborators on this work include Brain Cohen, Matthew Nickell, Sarah Ochel, Bianca Perez, Kendall Richards, and David Vaden. (Received September 12, 2014)

1106-05-1327 **Michael Krul***, 400 The Fenway, Boston, MA 02115, and **Lubos Thoma**, 5 Lippitt Rd, Kingston, RI 02881. *Algebraic Characterizations of Hypergraph Colorings.*

For a uniform hypergraph, we construct/present coloring scheme ideals in a polynomial ring over real numbers which characterize when the hypergraph admits a proper k-coloring with given restrictions on the *color patterns* on the edges. Using the coloring scheme ideals we provide full algebraic characterizations for various hypergraph coloring problems, including: list colorings, conflict-free colorings, strong colorings, and edge colorings. We also examine partial colorings and their effect on computing Gröbner bases for the polynomial ideals mention above.

Keywords: hypergraph, vertex coloring, list coloring, conflict-free coloring, edge coloring, polynomial ideal, Gröbner bases (Received September 12, 2014)

1106-05-1332 **Carolyn Chun*** (chchchun@gmail.com), John Crank 408, Brunel University London, Uxbridge, UB8 3PH, United Kingdom, and **Dillon Mayhew** and **James Oxley**. *A splitter theorem for internally 4-connected graphs.*

Tutte proved that every 3-connected graph that is not a wheel has an edge whose deletion is 3-connected or whose contraction is 3-connected. Seymour showed that, in addition to preserving 3-connectivity, removing an edge in the right way will preserve a pre-selected minor, as long as the minor is not a wheel. In this talk, we discuss these fundamental inductive tools and present analogues for internally 4-connected graphs. (Received September 12, 2014)

1106-05-1336 **Charles J Suer*** (suerchaj@gmail.com), University of Louisville, Department of Mathematics, 328 Natural Sciences Bldg, Louisville, KY 40292. *The PC-Tree Algorithm, the Torus, and Kuratowski Subdivisions.* Preliminary report.

The PC-Tree Algorithm of Shih and Hsu (1999) is a practical linear-time planarity algorithm that provides a plane embedding of the given graph if it is planar and a Kuratowski subdivision otherwise. We discuss extending the PC-Tree Algorithm to a polynomial-time toroidality algorithm, which would provide a torus embedding of the graph or a minimal obstruction to this. As a milestone toward this goal, we exhibit such an algorithm for $K_{3,3}$-free graphs. We also discuss a concept related to torus obstructions, the structure of graphs coverable with Kuratowski subdivisions. (Received September 12, 2014)

1106-05-1349 **Bonnie C. Jacob** and **Jobby Jacob*** (jxjsma@rit.edu). *Graph rankings based on l_p norms.*

For a graph G, a function $f : V(G) \to \{1, 2, \ldots, k\}$ is a k-ranking, if $f(u) = f(v)$ implies that every $u - v$ path contains a vertex x such that $f(x) > f(u) = f(v)$. The rank number of a graph G is the minimum value of k such that G has a k-ranking. Hence the rank number of a graph is obtained by applying the l_∞ norm (max norm) to the vertex labels. Jamison and Narayan studied the rank numbers of graphs based on the l_1 norm (sum norm).

In this talk, we will look at rank numbers of graphs based on l_p norms for $0 < p < \infty$. We will compare rank numbers based on l_p norms for $0 < p < \infty$ to the traditional rank numbers for different classes of graphs. We will show that there are graphs such that the set of traditional optimal rankings and the set of l_p optimal rankings are disjoint. (Received September 12, 2014)

1106-05-1352 **Brett C. Smith*** (bcsmith@wesleyan.edu). *Replacing square grids with triangular grids in Robertson and Seymour.*

The $n \times n$-grid is the canonical example of a planar graph of treewidth n, and it plays a pivotal role in setting up the base case in Robertson and Semour's proof of the Graph Minors Theorem. Their choice of the square grid relies on both its symmetry and simplicity. However, the $n \times n$-grid is far from being a *minimal* planar graph of treewidth n with respect to the minor relation.

We show that the triangular grids provide another family of graphs which realize every integer treewidth, and we characterize minimal structure common to both the triangular grids and the square grids. Moreover, we seek to use this structure to improve both algorithmic and theoretical lower bounds on treewidth. (Received September 12, 2014)

1106-05-1361 **Blanche Sonia Ngo Mahop** (bngomahop@smith.edu), Department of Mathematics, Smith College, Northampton, MA 01063, and **Daryl Seaver** (dseaver@smith.edu), **Jasmine VanExel*** (jvanexel@smith.edu), **Katherine Weber** (kweber@smith.edu) and **Ruth Haas** (rhaas@smith.edu). *Rainbow boxes in grid graphs.* Preliminary report.

We consider the following problem from extremal graph theory. What is the minimum k needed so that for every k coloring of the edges of an $n \times m$ grid there will be a square each of whose edges is a different color? A subgraph each of whose edges receives a different color is often called rainbow, or achromatic. Other authors have considered problems of similar flavor including rainbow matchings and rainbow complete graphs, typically considering these as subgraphs of colored complete graphs. (Received September 12, 2014)

1106-05-1477 **Justin Z. Schroeder*** (jzschroeder@gmail.com), **M. J. Grannell** and **T. A. McCourt**. *Self-embeddings of doubled Steiner triple systems.*

The faces in each color class of a face 2-colorable triangular embedding of the complete graph K_n form a Steiner triple system of order n, briefly STS(n); a *biembedding* of the STS(n)s S_1 and S_2 is such an embedding of K_n

in which the faces form systems isomorphic to S_1 and S_2. If, furthermore, S_1 and S_2 are isomorphic, then the biembedding is called a *self-embedding* of S_1. Given an STS(n) S and a 1-factorization $\mathcal{F} = \{F_1, F_2, ..., F_n\}$ of K_{n+1}, we can form an STS($2n+1$) S' by adding to S all triples of the form $\{x_i, a, b\}$, where $x_i \in S$ and $ab \in F_i$; S' is said to be a *doubling* of S. In this talk, we explore self-embeddings of doubled cyclic Steiner triple systems, doubled affine Steiner triple systems, and doubled projective Steiner triple systems. (Received September 13, 2014)

1106-05-1491 **Alex Lombardi*** (alexlombardi01@college.harvard.edu). *Distinguishing extension numbers for* $\mathbf{R}^n$ *and* S^n.

Let G be a group acting on a set X. The distinguishing number $D_G(X)$ is the smallest k such that there exists a k-coloring $c : X \to \{1, .., k\}$ which distinguishes the action of G on X (the only element of G that fixes c is the identity). Fixing $k = D_G(X)$, a subset $W \subset X$ with trivial pointwise stabilizer satisfies the precoloring extension property $P(W)$ if every k-coloring of $X - W$ can be extended to a G-distinguishing k-coloring of X. The distinguishing extension number $ext_D(X, G)$ is then defined to be the minimum n such that for all applicable $W \subset X$, $|W| \geq n$ implies that $P(W)$ holds. We compute $ext_D(X, G)$ in two particular instances: when $X = S^1$ is the unit circle and $G = \mathrm{Isom}(S^1) = O(2)$, and when $X = V(C_n)$ is the set of vertices of the cycle of order n and $G = \mathrm{Aut}(C_n) = D_n$. This resolves two conjectures of Ferrara, Gethner, Hartke, Stolee, and Wenger. In the case of $X = \mathbf{R}^2$, we prove that $ext_D(\mathbf{R}^2, SE(2)) < \infty$, which is consistent with (but does not resolve) another conjecture of Ferrara et al. We also prove that for all $n \geq 3$, $ext_D(S^{n-1}, O(n)) = \infty$ and $ext_D(\mathbf{R}^n, E(n)) = \infty$, disproving two other conjectures from the same authors. (Received September 13, 2014)

1106-05-1558 **Harold Matthew Williams*** (hwilliams@math.utexas.edu), Austin, TX 78756. *Cluster Integrable Systems and Categorification.*

We discuss recent work relating the study of integrable systems on cluster varieties with the categorification of cluster algebras via representations of quivers with potential. The quiver-theoretic approach provides many new insights into integrability, in particular illuminating its geometric and physical meaning. (Received September 14, 2014)

1106-05-1610 **Vivian Kuperberg*** (vzk2@cornell.edu). *Hadamard matrices modulo p and small modular Hadamard matrices.*

We use modular symmetric designs to study the existence of Hadamard matrices modulo certain primes. We solve the 7-modular and 11-modular versions of the Hadamard conjecture for all but a finite number of cases. In doing so, we state a conjecture for a sufficient condition for the existence of a p-modular Hadamard matrix for all but finitely many cases. When 2 is a primitive root of a prime p, we conditionally solve this conjecture and therefore the p-modular version of the Hadamard conjecture for all but finitely many cases when $p \equiv 3 \pmod 4$, and prove a weaker result for $p \equiv 1 \pmod 4$. Finally, we look at constraints on the existence of m-modular Hadamard matrices when the size of the matrix is small with respect to m. (Received September 14, 2014)

1106-05-1672 **Futaba Fujie*** (futaba@math.nagoya-u.ac.jp), Graduate School of Mathematics, Furo-cho, Chikusa-ku, Nagoya, 464-8602, Japan. *Paths in Hamiltonian graphs.*

One of the questions we often ask when a graph is studied is if it has a cycle that contains all of its vertices, that is, if the graph is Hamiltonian or not. A concept concerning paths in Hamiltonian graphs and several related results will be presented. (Received September 14, 2014)

1106-05-1690 **Suhyung An** (hera1973@yonsei.ac.kr), Yonsei University, Seoul, South Korea, **JiYoon Jung*** (jjung@nims.re.kr), National Institute for Mathematical Sciences, Daejeon, South Korea, and **Sangwook Kim** (swkim.math@chonnam.ac.kr), Chonnam National University, Gwangju, South Korea. *Face Structures of Lattice Path Matroid Polytopes.*

For two lattice paths P and Q from $(0,0)$ and (m,r) using east and north steps such that P is weakly below Q, a lattice path matroid $M(P,Q)$ is a transversal matroid whose bases can be identified with lattice paths from $(0,0)$ to (m,r) which lie in a region bounded by P and Q. The polytope whose vertices are the incidence vectors of the bases of $M(P,Q)$ is called a lattice path matroid polytope.

In this talk, we describe all the faces of a lattice path matroid polytope by restriction, contraction, and direct sum of lattice path matroid polytopes. We also find simple expression of the cd-index of a lattice path matroid polytope using cd-indices of lattice path matroid polytopes corresponding to border strips. (Received September 15, 2014)

1106-05-1694 **Gretchen L. Matthews*** (gmatthe@clemson.edu), Department of Mathematical Sciences, Clemson University, Clemson, SC 29634-0975. *Code parameters and graph coloring.*

In the theory of error-correcting codes, parameters are used to estimate the efficiency and error-correcting capability of a code as well as to determine the best possible codes with certain properties. In this talk, we consider parameters relevant to coding theory and apply them to graph coloring problems. (Received September 15, 2014)

1106-05-1753 **Sergey Fomin** and **Pavlo Pylyavskyy*** (pylyavskyy@gmail.com). *Webs on surfaces, rings of invariants, and clusters.*

We construct and study cluster algebra structures in rings of invariants of the special linear group action on collections of three-dimensional vectors, covectors, and matrices. The construction uses Kuperberg's calculus of webs on marked surfaces with boundary. (Received September 15, 2014)

1106-05-1764 **Aaron M. Montgomery*** (amontgom@bw.edu), Department of Mathematics & Computer Science, Baldwin Wallace University, Berea, OH 44130. *An Asymptotic Formula for the Number of Balanced Incomplete Block Design Incidence Matrices.*

We identify a relationship between a random walk on a certain Euclidean lattice and incidence matrices of balanced incomplete block designs, which arise in combinatorial design theory. We then compute the return probability of the random walk and use it to obtain the asymptotic number of BIBD incidence matrices (as the number of columns increases). Our strategy is similar in spirit to the one used by de Launey and Levin to count partial Hadamard matrices. (Received September 15, 2014)

1106-05-1768 **James P. Solazzo*** (jsolazzo@coastal.edu), Department of Mathematics, P.O. Box 261954, Conway, SC 29526, and **Thomas R. Hoffman**. *Complex Two-graphs via Equiangular Tight Frames.*

In 'A survey of two-graphs', J.J. Seidel lays out the connections between simple graphs, two-graphs, equiangular lines and strongly regular graphs. It is well known that there is a one-to-one correspondence between regular two-graphs and equiangular tight frames. This presentation gives a generalization of two-graphs for which these connections can be mimicked using roots of unity beyond ± 1. Many of the results for two-graphs have a natural generalization for complex two-graphs. (Received September 15, 2014)

1106-05-1829 **Christian Borgs** and **Jennifer T Chayes*** (jchayes@microsoft.com), Microsoft Research, One Memorial Drive, Cambridge, MA 02142, and **Henry Cohn** and **Yufei Zhao**. *An L^p theory of sparse graph limits I: limits, sparse random graph models, and power law distributions.*

We introduce and develop a theory of limits for sequences of sparse graphs based on L^p graphons, which generalizes both the existing L^∞ theory of dense graph limits and its extension by Bollobás and Riordan to sparse graphs without dense spots. In doing so, we replace the no dense spots hypothesis with weaker assumptions, which allow us to analyze graphs with power law degree distributions. This gives the first broadly applicable limit theory for sparse graphs with unbounded average degrees. (Received September 15, 2014)

1106-05-1830 **Allen J. Schwenk*** (schwenk@@wmich.edu), Western Michigan UIniversity, Department of Mathematics, 1903 W. Michigan Ave., Kalamazoo, MI 49008-5248, and **Stan Wagon** (wagon@macalester.edu), Macalester College, Department of Mathematics, St. Paul, MN 55105-1899. *Title: Knight Tours on Triangular and Hexagonal Boards.* Preliminary report.

An analog of the knight's move is defined on boards with hexagonal cells. We determine which triangular and hexagonal boards admit a knight's tour. Small examples and proof by induction settles the problem for all sizes. (Received September 15, 2014)

1106-05-1834 **Christian Borgs**, **Jennifer T Chayes** and **Henry Cohn*** (cohn@microsoft.com), Microsoft Research, One Memorial Drive, Cambridge, MA 02142, and **Yufei Zhao**. *An L^p theory of sparse graph convergence II: LD convergence, quotients, and right convergence.*

We extend the L^p theory of sparse graph limits by analyzing different notions of convergence. Under suitable restrictions on node weights, we prove the equivalence of metric convergence, quotient convergence, microcanonical ground state energy convergence, microcanonical free energy convergence, and large deviation convergence. Our theorems extend the broad applicability of dense graph convergence to all sparse graphs with unbounded average degree, while the proofs require new techniques based on uniform upper regularity. Examples to which our theory applies include stochastic block models, power law graphs, and sparse versions of W-random graphs. (Received September 15, 2014)

1106-05-1837 **Christian Borgs*** (`borgs@microsoft.com`), Microsoft Research, One Memorial Drive, Cambridge, MA 02142. *Non-parametric block model estimation for sparse graphs.* Preliminary report.

When analyzing large networks, statisticians often assume a generative model in which the observed graph is assumed to come from a stochastic block model, i.e., a random graph with inhomogeneous edge probabilities given in terms of a small block matrix. A non-parametric version of these stochastic block models are so-called W-random graphs, given in terms of an integrable, symmetric function W on the unit square. In this talk I discuss the question on how to recover a good approximation to W from just a single sample of a W-random graph, and relate it to the theory of convergence of sparse graphs. (Received September 15, 2014)

1106-05-1848 **Ryan L Kaliszewski*** (`rlk72@drexel.edu`), Department of Mathematics, Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104, and **Huilan Li**. *Symmetry of the rational q,t-Catalan numbers for $3,n$-Dyck paths.*

The Catalan numbers are one of the most classical of integer sequences. The more general "(m,n)-rational Catalan numbers", count Dyck paths inscribed in an $n \times m$ integer lattice where n and m are coprime, have been the subject of recent attention as it has been discovered that they are connected to many classical and contemporary theories. For example, they are in bijection with a subset of elements in the Coxeter group of type-A.

The rational q,t-Catalans are polynomials in two parameters t and q defined by summing $q^{area(\pi)}t^{dinv(\pi)}$ over all Dyck paths π in the $n \times m$ integer lattice, where $(area(\pi), dinv(\pi))$ is a distinguished pair of non-negative integers associated to each path π. Of particular interest is the conjecture that the rational Catalan numbers are symmetric in q and t.

We prove the cases when $m = 2$ and $m = 3$ by describing the *rank word* of a m,n-Dyck path, which is an increasing list of the positive ranks of the cells in the diagram that highlights those ranks associated to cells lying above the path. The rank words uniquely determine the n,m-Dyck paths when $m = 2$ and $m = 3$ and allow construction of an involution on these paths that exchange the *dinv* and *area* statistics. (Received September 15, 2014)

1106-05-1874 **Albert R. Bush*** (`albertbush@gmail.com`) and **Ernie Croot**. *Few Products, Many h-fold Sums: Progress on the Multi-fold Sum-Product Problem in the Reals.*

The well-known sum-product conjecture of Erdős and Szemerédi states that either the sumset $A + A$ or the product set $A.A$ are nearly maximal in size, $\Omega(|A|^{2-\epsilon})$. They made a similar conjecture that the h-fold sumset or the h-fold product set is of size $\Omega(|A|^{h-\epsilon})$. While resolution of the h-fold conjecture is currently out of reach, weaker forms have seen some success. Chang proved that if A is a set of integers and $|A.A| \leq K|A|$, then the h-fold sumset of A is of size $\Omega_K(|A|^h)$. However, if A is a set of reals, the best known bounds have all been much weaker: $O(|A|^{\log h})$. We prove the first bound that is stronger than logarithmic in the exponent: $|A|^{\exp(\sqrt{\log h})}$. Our proof incorporates the graph-theoretic technique of dependent random choice, a bound on the Tarry-Escott problem in number theory, and well-known additive combinatorial tools. (Received September 15, 2014)

1106-05-1879 **Emily Gunawan*** (`egunawan@umn.edu`) and **Gregg Musiker** (`musiker@umn.edu`). *T-Path Formula and Atomic Bases for Cluster Algebras of Type D.*

Cluster algebras, introduced by Fomin and Zelevinsky in 2000, are integral domains equipped with a set of generators, called *cluster variables*, which can be constructed recursively starting from an initial set of n cluster variables. We investigate the existence of *atomic bases* for cluster algebras arising from certain surfaces with marked points. Our results thus far are an extension of a T-path formula for cluster variables and a combinatorial proof that *cluster monomials* (i.e. products of compatible cluster variables) form the atomic basis of a cluster algebra coming from a once-punctured polygon (type D). (Received September 15, 2014)

1106-05-1886 **Robert Davis*** (`davis.robert@uky.edu`), Department of Mathematics, 715 Patterson Office Tower, University of Kentucky, Lexington, KY 40506. *Integrally Closed Polytopes and an Application to Symmetric Magic Squares.*

It is an open question in Ehrhart theory to determine when the h^*-vector of a rational polytope is unimodal. While unimodality is difficult to prove in even highly restrictive situations, if the polytope is integrally closed then tools from commutative algebra can be useful. We will discuss new applications of toric algebra to certain families of integer polytopes formed from symmetric magic squares. (Received September 15, 2014)

1106-05-1920 **Mark Kempton*** (mkempton@ucsd.edu), Department of Mathematics, University of California, San Diego, 9500 Gilman Drive #0112, San Diego, CA 92093. *The Mixing Rate of Non-backtracking Random Walks of Graphs.*

Given a graph G, a random walk on G is a sequence of vertices $v_0, v_1, v_2, \ldots.$ in which the vertex v_k is chosen randomly among the neighbors of v_{k-1}. Random walks on graphs are well studied, and many tools from spectral graph theory are used in the analysis of properties of random walks. A *non-backtracking* random walk is a random walk in which $v_{k+1} \neq v_{k-1}$. That is, at any step in the random walk, we are restricted only to the vertices not visited on the previous step. Non-backtracking random walks are somewhat more difficult to analyze, although results on their mixing rate exist for regular graphs. We will apply spectral tools to discuss the mixing rate of non-backtracking random walks on more general graphs. In particular, we present a weighted version of a result known as Ihara's Theorem to analyze the spectrum of the transition probability matrix describing a non-backtracking random walk on a graph. (Received September 15, 2014)

1106-05-1943 **Emily Barnard***, esbarnar@ncsu.edu, and **Nathan Reading**. *The TwinSort Congruence.* Preliminary report.

Sortable elements provide a model for finite type cluster algebras. They are obtained from a Coxeter group via a lattice congruence on the weak order called the Cambrian congruence. I will discuss the common refinement of two opposite bipartite Cambrian congruences, called the TwinSort congruence. The fan associated to this congruence is the common refinement of the g-vector fan for the opposite bipartite type cluster algebra. The TwinSort congruence has beautiful enumerative and geometric properties in type A, which I will discuss using non-crossing arc diagrams. (Received September 15, 2014)

1106-05-1967 **Eric L Clark*** (eclark@kwc.edu). *Enumerating Q-factorial Posets.* Preliminary report.

For posets P and Q, P is said to be Q-factorial if 1.) $i <_P j$ implies $i <_Q j$ and 2.) $i <_Q j <_P k$ implies $i <_P k$. These were first studied by Claesson and Linusson who showed that when Q was an n-chain, there were $n!$ posets P and that each was $(2+2)$-free. In this talk, we enumerate Q-factorial posets for other classes of posets Q. (Received September 15, 2014)

1106-05-1980 **Mercedes S. Coleman*** (mcoleman@lamar.edu), Lamar University, Dept of Math Box 10047, 211 Redbird LN, Beaumont, TX 77705-9801. *How to best defend against an attack that can't be thwarted.*

Let G=(V, E) be a finite simple graph. Security in G is the ability for S $\subseteq$ V to defend against any attack on the vertices of S. In an attack on S, each vertex in N(S)-S, where N(S) = {y$\in$V : xy$\in$E for some x$\in$S}, gets to attack one of its neighbors in S. In a defense of S, each vertex in S gets to defend itself or one of its neighbors in S. A defense of S thwarts an attack on S if every vertex of S has at least as many defenders as attackers. An algorithm is described for setting up a defense against an attack which can't be thwarted. (Received September 15, 2014)

1106-05-1995 **Peter Diao*** (peter.z.diao@gmail.com), **Dominique Guillot**, **Apoorva Khare** and **Bala Rajaratnam**. *Differential Calculus on Graphon Space.*

The beautiful theory of dense graph limits has received attention from many different viewpoints. In this talk, I will describe recent work on the structure of smooth graphon parameters. The talk will be structured into three main parts.

(1) A brief general introduction to the key topological properties of graphons.
(2) A description of a theorem that summarizes the general structure of the derivatives of smooth graphon parameters.
(3) An exposition of the main ideas of the proof, applications to homomorphism density expansions of smooth graphon parameters, and generalizations.

(Joint with D. Guillot, A. Khare, and B. Rajaratnam) (Received September 15, 2014)

1106-05-1998 **Vera T. Sós*** (t.sos.vera@renyi.mta.hu). *On sequences of dense graphs.*

I will give a selection of problems and results on sequences of dense graphs. In particular I will talk about the following:

(1) Problems related to the basic, equivalent properties of graph sequences,
(2) Some further (weaker?) definitions of convergence,
(3) Problems on some special families of convergent sequences of dense graphs.

(Received September 15, 2014)

1106-05-2001 **Apoorva Khare*** (khare@stanford.edu) and **Bala Rajaratnam** (brajarat@stanford.edu). *Differential calculus on the space of countable labelled graphs.*

I will discuss recent work on limits of labelled graphs. We show interesting parallels to the graphon literature, including a representation theory that metrizes convergence of "homomorphism indicators", a Counting Lemma, and compactness of the space of all limit objects. However, there are significant differences with graphons because of sampling issues. We also develop a theory of differentiation on labelled graph space, including a First Derivative Test. (Joint with Bala Rajaratnam) (Received September 15, 2014)

1106-05-2023 **Dennis Eichhorn***, Department of Mathematics, University of California, Irvine, Irvine, CA 92697, and **Felix Breuer** and **Brandt Kronholm**. *The Combinatorics Governing the Periodicity of $p(n,d)$ Modulo M.*

Since the generating function for $p(n,d)$, the number of partitions of n into parts of size at most d, is a rational function, we know that $p(n,d)$ is periodic modulo M. Can one find a purely combinatorial explanation for the periodicity?

The search for an explanation led us to study the geometry of lattice points in polyhedra, which ultimately inspired a new decomposition of partitions into their "ℓ-box remainder" and "ℓ-box quotient." These two new objects bear many similarities to the ℓ-core and ℓ-quotient of a partition, which were used in the famous combinatorial proof of the first four Ramanujan congruences by Garvan, Kim, and Stanton. This new ℓ-box decomposition does lead to a combinatorial proof of the periodicity of $p(n,d)$ modulo M, and the proof provides substantial structural information about the behavior of $p(n,d)$.

Some immediate consequences of this work include new proofs of several infinite families of known Ramanujan-type congruences for $p(n,d)$. Furthermore, these methods apply equally well to partitions whose parts come from any fixed finite set A, which allows for many new generalizations of the previously known infinite families of congruences. (Received September 15, 2014)

1106-05-2040 **Salvatore Tringali*** (salvo.tringali@gmail.com), Texas A&M University PO Box 23874, Doha, Qatar. *On the structure of sets of lengths in η-systems.* Preliminary report.

Let $\Phi = (\mathbb{S}, \|\cdot\|, \mathfrak{P}, \Theta, \mathcal{E})$ be a (natural) η-system, i.e., $\mathbb{S} = (S, \cdot)$ is a semigroup, $\|\cdot\|$ is a seminorm $\mathbb{S} \to (\mathbf{N}, +, \le)$, $\mathfrak{P}$ and Θ are subsets of S with Θ disjoint from the subsemigroup generated by $\mathfrak{P}$, and $\mathcal{E}$ is an equivalence on $\mathfrak{P}^\dagger$ (here, $X^\dagger$ means the Kleene plus of a set X).

Let σ be the factorization map $S^\dagger \to S : (x_1, \ldots, x_n) \mapsto x_1 \cdots x_n$. For each $k \in \mathbf{N}^+$ we let $\mathcal{U}_k$ be the set of all integers l for which there exist *minimal* Φ-factorizations $\mathfrak{p} = (p_1, \ldots, p_m), \mathfrak{q} = (q_1, \ldots, q_n) \in \mathfrak{P}^\dagger$ such that $\sigma(\mathfrak{p}) = \sigma(\mathfrak{q})$, $\sum_{i=1}^m \|p_i\| = k$ and $\sum_{i=1}^n \|q_i\| = l$. We show that this generalizes sets of lengths, as defined in the factorization theory of monoids, to η-systems.

We say that Φ is atomic if $\Theta \cup \sigma(\mathfrak{P}^\dagger) = S$, and smoothly bounded if $\varrho_k := \sup(\mathcal{U}_k) < \infty$ for each k and $\sup_{k \ge 1}(\varrho_{k+1} - \varrho_k) < \infty$. We give examples of [atomic] smoothly bounded η-systems and prove that if Φ is smoothly bounded then the $\mathcal{U}_k$'s have a non-trivial additive structure. (Received September 16, 2014)

1106-05-2058 **Jeong-Ok Choi** (jchoi351@gist.ac.kr), Gwangju Inst. of Science and Technology, Gwangju, South Korea, **John P Georges** (john.georges@trincoll.edu), Math Dept., Trinity College, Hartford, CT 06106, and **David Mauro*** (david.mauro@trincoll.edu), Math Dept., Trinity College, Hartford, CT 06106. *On a pursuit-evasion model without instantaneous movement.*

Given a simple graph G, we consider a vertex search model under which pursuers and evaders move along edges at finite speed and reside on vertices at integral times. An evader is captured by a pursuer if and only if one of the following occurs: (a) at integral time t, the pursuer and the evader occupy the same or adjacent vertices; (b) between integral times $t-1$ and t, the evader passes through a vertex incident to an edge containing the pursuer; (c) between integral times $t-1$ and t, the evader passes through a vertex that is adjacent to a vertex containing the pursuer. Letting $w(G)$ denote the minimum number of pursuers required to guarantee the capture of all evaders in finite time, we explore conditions under which $w(G)$ is at least $w(H)$ for subgraph H of G. We consider the relationship between $w(G)$ and graph invariants such as girth, diameter, and minimum degree. We determine $w(G)$ for G in various classes of graphs, with emphasis on trees. And, we extend the model to one of greater generality in which evaders may have edges as destinations at integral times. (Received September 15, 2014)

1106-05-2062 **Chelsea M Lawhorn*** (lawhornc2@winthrop.edu), 251 E Jonest St, Blacksburg, SC 29702, and **Joseph Rusinko**. *Path Systems: A New Systematic Approach to Finding Quartets.*

Phylogenetic trees, or topological representations of evolutionary data, are constructed using groupings of paired taxa known as quartets. The number of quartets which could accurately describe a tree is very large, roughly T4 where T is the number of taxa on a tree. Because the total number of compatible quartets which could define a tree is so extensive, it would be helpful to find an algorithm which could systematically choose a subset of quartets which would return a correct tree using MaxCut, a computer software program which returns a phylogenetic tree using the quartets it is given. Currently, quartet amalgamation systems focus on quartets which distinguish single edges on a phylogenetic tree. However, in this work, we explore a new way of creating quartets, known as a path system, in which the quartets not only distinguish single edges, but also distinguish paths of adjacent edges. We discover how a path system uses consistent taxa pairs in the quartets it creates in order to help MaxCut return a correct tree. In addition, we find that path systems not only consistently return a correct tree using MaxCut, but do so using a significantly fewer number of quartets than other systems. (Received September 15, 2014)

1106-05-2087 **David Rolnick** (drolnick@math.mit.edu) and **Praveen S. Venkataramana*** (venkap@mit.edu). *On the growth of Stanley sequences.*

A set is said to be *3-free* if no three elements form an arithmetic progression. Given a 3-free set A of integers $0 = a_0 < a_1 < \cdots < a_t$, the *Stanley sequence* $S(A) = \{a_n\}$ is defined using the greedy algorithm: For each successive $n > t$, we pick the smallest possible a_n so that $\{a_0, a_1, \ldots, a_n\}$ is 3-free and increasing. Work by Odlyzko and Stanley indicates that Stanley sequences may be divided into two classes. Sequences of Type 1 are highly structured and satisfy $\alpha n^{\log_2 3}/2 \leq a_n \leq \alpha n^{\log_2 3}$, for some constant α, while those of Type 2 appear chaotic and satisfy $\Theta(n^2/\log n)$. In this paper, we consider the possible values for α in the growth of Type 1 Stanley sequences. Whereas Odlyzko and Stanley assumed that $\alpha = 1$, we show that α can be any rational number that is at least 1 and for which the denominator, in lowest terms, is a power of 3. (Received September 15, 2014)

1106-05-2101 **Michael Anthony Rosas*** (marosas@buffalo.edu). *On the structure of Specht modules in the principal block of $F\Sigma_{3p}$.*

We discuss the Loewy structures of Specht modules in the principal block of $F\Sigma_{3p}$, where F is a field of characteristic $p \geq 5$. An upper bound on the Loewy lengths is given, and a condition is provided so that a Specht module attains the maximum possible Loewy length. This condition allows one to describe the Loewy structures of certain Specht modules from the Ext^1-quiver for the principal block of $F\Sigma_{3p}$. (Received September 15, 2014)

1106-05-2128 **Padmapani Seneviratne*** (padmapani.seneviratne@tamuc.edu), Department of Mathematics, Texas A&M University, P.O. Box 3011, Commerce, TX 75429-3011. *$(0,2)$-graphs and their codes.* Preliminary report.

Binary codes obtained from the neighborhood designs of $(0,2)$-graphs Γ, the cartesian product $2\Gamma = \Gamma \times K_2$ and their reflexive graphs $\widetilde{\Gamma}$ and $\widetilde{2\Gamma}$ are introduced. We show that the binary codes from the neighborhood designs of 2Γ and $\widetilde{2\Gamma}$ are self-dual. Further, bounds on the minimum distance and partial weight distributions of these codes are obtained. In particular, we show that many optimal binary self-dual codes can be obtained by this construction method. (Received September 15, 2014)

1106-05-2133 **Amol Aggarwal*** (agg_a@mit.edu), CA. *A Converse to Vandehey's Theorem on Simultaneous Core Containment.*

In response to a question of Olsson and Stanton in 2007, Vandehey showed that there exists an (a, b)-core that contains every other (a, b)-core as a subpartition when $\gcd(a, b) = 1$. In this paper we establish a converse to Vandehey's theorem by showing that, if $a < b < c$ are pairwise relatively prime positive integers, then there exists an (a, b, c)-core containing every other (a, b, c)-core if and only if c is in the numerical semigroup generated by a and b. As a corollary, we generalize a result of Olsson and Stanton that expresses the largest (a, b)-core explicitly in terms of a and b when $\gcd(a, b) = 1$. (Received September 15, 2014)

1106-05-2155 **Zoltan Furedi** and **Zeinab Maleki*** (zmaleki@math.iut.ac.ir), 515 4th St SE, Apt 304, Minneapolis, MN 55414. *On Erdos' conjecture on the number of edges in 5-cycles.*

Erdös, Faudree, and Rousseau in 1992 showed that a graph on n vertices and with at least $\lfloor n^2/4 \rfloor + 1$ edges comprise at least $2\lfloor n/2 \rfloor + 1$ edges on triangles and this result is sharp. They also considered a conjecture of

Erdös that such a graph have at most $n^2/36$ non-pentagonal edges. This was mentioned in other paper of Erdös and also in Fan Chung's problem book.

In this talk we give a graph of $\lfloor n^2/4 \rfloor + 1$ edges with much more, namely $n^2/8(2+\sqrt{2}) + O(n)$ pentagonal edges, disproving the original conjecture. We also show that this coefficient is asymptotically the best possible. (Received September 15, 2014)

1106-05-2157 **Thomas C Hull*** (thull@wne.edu). *Origami mountain-valley assignments and graph colorings.*

An *origami crease pattern* is a planar graph drawn on a bounded region (the piece of paper) that represents the creases made for a paper-folded object. A *flat origami* crease pattern is, intuitively, an origami crease pattern that will fold into an object that can be pressed in a book without crumpling or adding new creases. The creases in an origami model come in two types: *Mountains*, which are convex, and *valleys*, which are concave. An assignment of mountains and valleys to a flat origami crease pattern is called *valid* if it allows the crease pattern to be folded flat without the paper self-intersecting. In this talk we will describe how mountain-valley assignments of flat origami crease patterns are equivalent to various graph coloring problems. Surprisingly, only the simplest cases are equivalent to a 2-coloring of a graph, where the mountains correspond to one color and the valleys to another. Some crease patterns correspond to 3-colorings of certain graphs and lead to interesting connections with Ising models. This work is supported by NSF grant EFRI-ODISSEI-1240441. (Received September 15, 2014)

1106-05-2217 **John S. Caughman**, **Charles L. Dunn**, **Joshua D. Laison*** (jlaison@willamette.edu), **Nancy Ann Neudauer** and **Colin L. Starr**. *Minimum Representations of Rectangle Visibility Graphs.* Preliminary report.

Let S be a set of nonintersecting open rectangles in the plane with horizontal and vertical sides. Two rectangles R_1 and R_2 are *visible* if there exists a *line of sight* between them, a horizontal or vertical line segment that intersects both R_1 and R_2 but no other object in S. We construct a graph G with a vertex for each rectangle in S, and an edge between two vertices if and only if their corresponding rectangles are visible. For a given graph G, if such a representation of G with rectangles exists then G is a *rectangle visibility graph* (*RVG*) and S is a *rectangle visibility representation* of G. Suppose the corners of the rectangles in S have integer coordinates. For a given RVG G, we ask how small its rectangle visibility representation can be. We think of the size of a rectangle visibility representation as the area of the smallest axis-parallel rectangle that encloses it (the *area* of S), or as the length of the shorter side of this rectangle (the *height* of S). We find the height of a rectangle visibility representation of a tree. We also ask for the RVG with n vertices and largest area. We begin answering this question for small values of n. (Received September 16, 2014)

1106-05-2242 **Kathryn Haymaker***, kathryn.haymaker@villanova.edu. *Constructions of codes for the grain-error model.* Preliminary report.

In 2011 Mazumdar et al. proposed a combinatorial model of errors in high-density magnetic storage media. In this model, grains of varying sizes can be set to one of two polarities. When adjacent bit positions are contained in one grain, one of the bits can be forced into the wrong polarity by the grain, causing grain-errors. Recently, several authors have presented constructions of codes correcting single grain-errors, and bounds on the size of t-grain-correcting codes. In this talk we will introduce the notion of a grain-detecting set and present constructions of grain-correcting-codes for grains of different sizes. (Received September 16, 2014)

1106-05-2245 **Simon D Pfeil*** (spfeil2@lsu.edu), **James Oxley**, **Charles Semple** and **Geoff Whittle**. *Matroids with many small circuits and many small cocircuits.* Preliminary report.

A consequence of Tutte's Wheels-and-Whirls Theorem is that the only 3-connected matroids in which every element is in both a 3-element circuit and a 3-element cocircuit are the well-known wheels and whirls. Miller showed that a sufficiently large 3-connected matroid in which every pair of elements is contained in a 4-element circuit and a 4-element cocircuit must belong to another well-known family, namely spikes. This talk will consider several variants on these two results. (Received September 16, 2014)

1106-05-2272 **Tom Kelly*** (tjkelly@princeton.edu). *Abundance of Graph Statistics.*

We examine how many minimal dominating sets there can be in a graph with domination number γ. We provide an explicit construction and also use probabilistic methods to show the existence of a graph with domination number γ in which almost all sets of size γ dominate. Similarly, we present an explicit construction of a graph with diameter d, where almost all pairs of vertices are at distance d. In general, we ask about the "abundance" of instances in a graph that comprise a graph statistic. (Received September 16, 2014)

1106-05-2311 **Thomas Enkosky*** (thomas.a.enkosky@uscga.edu) and **Branden Stone**. *Connecting M-sequences with the Fibonacci sequence and integer partitions.*

In joint work with Stone, we found a connection between M-sequences, the Fibonacci sequence, and integer partitions into distinct parts. A *multicomplex* $\mathcal{M}$ is a set of monomials in d variables closed under division. Let m_i be the number of monomials in $\mathcal{M}$ of degree i. The associated *M-sequence* is $(m_0, m_1, m_2, \dots)$. Let L_n be the number of M-sequences where the terms of the sequence sum to n. That is, L_n counts the number of multicomplexes with n monomials. The first terms of the sequence $\{L_n\}_{n\geq 0}$ are $1, 1, 2, 3, 5, 8, 12, \dots$. We used a Fibonacci recurrence to show that this sequence is bounded above by the Fibonacci sequence. We restricted to the case $m_1 = 2$ to show that the sequence is bounded below by the number of integer partitions into distinct parts. (Received September 16, 2014)

1106-05-2342 **Jesse Taylor*** (jesse.taylor@angelo.edu). *Matroids in which all circuits are large.*

Almost all matroids are 3-connected. It is also widely believed that almost all matroids contain only large circuits. In this talk, we give the necessary preliminaries and an excluded-minor characterization of all 3-connected matroids in which all circuits are large. No knowledge of matroids will be assumed. (Received September 16, 2014)

1106-05-2356 **David Petrie Moulton*** (dpmoulton@gmail.com). *Are All 2-connected Maximal Non-Hamiltonian Graphs Spanned by θ Graphs?* Preliminary report.

One way to study Hamiltonicity of graphs is to consider (edge-)maximal non-Hamiltonian graphs. For instance, Ore's sufficient condition for a graph to be Hamiltonian can be rephrased as saying that in any maximal non-Hamiltonian graph of order n, there are two nonadjacent vertices whose degrees sum to less than n. In fact, the Bondy–Chvatal Theorem says that this property holds for every pair of nonadjacent vertices.

It is easy to show that every maximal non-Hamiltonian graph of order at least 3 is spanned by a figure-8 graph (the union of two cycles sharing a point, where we allow each cycle to degenerate to an edge). Now maximal non-Hamiltonian graphs with cut-vertices are easily classified, so we can restrict our attention to 2-connected maximal non-Hamiltonian graphs. I conjecture that every such graph is spanned by a θ graph (a subdivision of $K_{1,1,2}$). I have shown that this holds for all such graphs of order at most 20 and have proved a number of properties that a potential counterexample would have to possess. (Received September 16, 2014)

1106-05-2367 **Blair D. Sullivan*** (blair_sullivan@ncsu.edu). *Adding Structure to Network Science.*

Rapid growth in data is providing scientists with novel opportunities to improve understanding of complex systems but also with significant challenges in analysis. A key missing component is scalable methods that identify patterns and translate them into domain knowledge. One can naturally represent much of the data as graphs (encode relationships in edges), but this leads to a hodgepodge of ad hoc methods that often resort to heuristics as rigorous approaches don't scale.

On the other hand, the theoretical community has long known that graph structure can have a huge impact on algorithmic complexity- this is a primary tenet of fixed parameter tractability (FPT). Unfortunately, directly applying FPT algorithms is typically infeasible due to large hidden constants in the complexity and parameters' fragility to small edits of the edge set.

We discuss initial work on fitting real-world networks into the sparse graph hierarchy, using broader classes (e.g. bounded expansion), random graph models, and empirical evaluations. We also mention algorithmic advances, geometric tree-like structure (hyperbolicity), and applications in social networks/neuroscience. Joint work with E. Demaine, M. Farrell, T. Goodrich, N. Lemons, F. Reidl, P. Rossmanith, F. Sánchez Villaamil & S. Sikdar (Received September 16, 2014)

1106-05-2371 **Elizabeth Y. Yang*** (eyang@princeton.edu), 44 Birch Drive, Plainsboro, NJ 08536. *A study of competition graphs induced by permutations.* Preliminary report.

We introduce a means to unite two active areas of research: the study of competition graphs and the study of permutation patterns. We extend the work of Cho, Kim on competition graphs of doubly partial orders on points in $\mathbb{R}^2$. The competition graphs of permutations use the doubly partial order on the permutation's graphical representation. This has interesting enumerative implications as well; each edge in the competition graph corresponds to an instance of a 123 or a 132 pattern within the permutation.

We find ways to characterize which types of graphs can be competition graphs of certain collections of permutations. More interesting patterns arise when considering the competition graphs of permutations avoiding the pattern 132 (and similarly, 123). This motivates us to restrict our study to paths and stars. We will demonstrate some structural and enumerative results for these classes of competition graphs.

For example, we can produce bijections between permutations that produce paths and permutations that produce stars and a recurrence relation to compute these numbers quickly. Some analogous results were produced for sets of permutations avoiding the pattern 132 (and similarly, 123).

This was joint work with Brian Nakamura. (Received September 16, 2014)

1106-05-2394 **John R Greene*** (jgreene@d.umn.edu), Department of Mathematics and Statistics, University of Minnesota Duluth, Duluth, MN 55812. *Combinatorial properties of traces of matrix products.* Preliminary report.

Given two noncommuting matrices, A and B, it is well known that AB and BA have the same trace. This extends to cyclic permutations of products of A's and B's. Thus, for example, $AAAABB$, $BAAAAB$, $BBAAAA$, $ABBAAA$, $AABBAA$ and $ABABBA$ all have the same trace. This means that if A and B are fixed matrices then products of four A's and two B's can have 3 possible traces. For 2×2 matrices A and B we show that there are restrictions on the relative sizes of these traces. For example, if $M_1 = A^4B^2$, $M_2 = A^3BAB$ and $M_3 = A^2BA^2B$ then it is never the case that $Trace(M_1) > Trace(M_3) > Trace(M_2)$. For larger collections of A's and B's, forbidden orders become much more common. In this talk, these and similar results are discussed. (Received September 16, 2014)

1106-05-2397 **Scott Lacy*** (scott.lacy@mavs.uta.edu). *Sub-neofields of finite D-neofields.*

A neofield is a set with two binary operations similar to a field, with the addition not necessarily associative and the multiplication not necessarily commutative. Neofields offer considerable advantages in the design of cryptographic algorithms and enciphering systems, yet typically only associative structures such as groups, fields and vector spaces are used in practice. Property D cyclic neofields have a cyclic multiplicative group and are named D-neofields due to a special "divisibility" property. The existence of a D-neofield of a particular order guarantees the existence of a pair of orthogonal latin squares. D-neofields have been classified to order 20 and conjectured to exist for all orders beyond by A.D Keedwell in 1967. Many examples of larger orders have been found, including all commutative neofields to order 28. In this talk we explore the concept of a sub-neofield and consider the implication on extending neofields to much larger neofields. In particular we examine D-neofields of order 25, along with examples of their subneofields. (Received September 16, 2014)

1106-05-2400 **Curtis Clark*** (curtis.clark@morehouse.edu), Department of Mathematics, Morehouse College, 830 Westview Drive, Atlanta, GA 30314. *On $2-2$ Graph Achievement Games.* Preliminary report.

Let F be a graph with no isolated vertices. The $2-2$ F-achievement game on the complete graph K_n is described as follows. Player A first colors two edges of K_n green. Then Player B colors two different edges of K_n red. They continue alternatively coloring the edges with Player A coloring two edges green and Player B coloring two edges red. The graph F is achievable on K_n if Player A can make a copy of F in his color. The minimum n such that F is achievable on K_n is the $2-2$ achievement number of F, $a(F)$. The $2-2$ move number of F, $m(F)$, is the least number of edges that must be colored by Player A to make F on the complete graph with $a(F)$ vertices. We determine $a(F)$ and $m(F)$ for some small graphs, paths, and cycles. Then we compare these results with those for $1-1$, $2-1$, and $1-2$ graph achievement games. (Received September 16, 2014)

1106-05-2434 **Danny Rorabaugh*** (rorabaug@email.sc.edu) and **Joshua Cooper** (cooper@math.sc.edu). *Avoidability and Density of Words.*

Many interesting Ramsey-type and Turán-type questions about subgraph homomorphisms can also be asked about subword homomorphisms. We say that word W encounters word V provided there is a nonerasing homomorphism ϕ such that $\phi(V)$ is a factor of W, that is, a subword of consecutive letters. A word V is unavoidable if, over every finite alphabet, every sufficiently long word encounters V. In 1982, Zimin classified all unavoidable words. Here we establish bounds for the associated Ramsey-type question: How long can words be that avoid unavoidable words? We also explore preliminary theory of subword homomorphism densities, which arose from our study of avoidability. (Received September 16, 2014)

1106-05-2439 **Zachary Higgins*** (zhiggins@ufl.edu). *Universal Cycles of k-Partitions of $[n]$.* Preliminary report.

We study universal cycles of the set $P_{n,k}$ of k-partitions of the set $[n]$ and prove that the transition digraph associated with $P_{n,k}$ is Eulerian. We use this result to prove that U-cycles of $P_{n,k}$ exist for all $n \geq 3$ when $k = 2$

and for odd n when $k = n - 1$. We also prove that U-cycles do not exist for n even when $k = n - 1$ or when $S(n-2, k-2)$ is odd $(3 \leq k < n-1)$. (Received September 16, 2014)

1106-05-2443 **Nathan Reading** and **Salvatore Stella*** (sstella@ncsu.edu). *Initial-seed recursions and dualities for* **d***-vectors.*

Cluster variables in a cluster algebra can be parametrized by two families of integer vectors: **d**-vectors and **g**-vectors. While **g**-vectors satisfy two recursive formulas (one for initial-seed-mutations and one for final-seed-mutations), **d**-vectors admit only a final-seed-mutation recursion.

In this talk we present an initial-seed-mutation formula for **d**-vectors that holds in a varied collection of cluster algebras, but not in general. We also give two rephrasings of this recursion: one as a duality formula for **d**-vectors in the style of the **g**-vectors/**c**-vectors dualities of Nakanishi and Zelevinsky, and one as a formula expressing the highest powers in the Laurent expansion of a cluster variable in terms of the **d**-vectors of any cluster containing it. (Received September 16, 2014)

1106-05-2466 **Franklin H. J. Kenter*** (franklin.h.kenter@rice.edu). *Eigenvector Norms Matter in Spectral Graph Theory.*

We investigate the role of eigenvector norms in spectral graph theory to various combinatorial problems including the densest subgraph problem, the Cheeger constant, among others. We introduce randomized spectral algorithms that produce guarantees which, in some cases, are better than the classical spectral techniques. In particular, we will give an alternative Cheeger "sweep" (graph partitioning) algorithm which provides a linear spectral bound for the Cheeger constant at the expense of an additional factor determined by eigenvector norms. Finally, we apply these ideas and techniques to problems and concepts unique to directed graphs. (Received September 16, 2014)

1106-05-2467 **Alexander Craig Madaus*** (amadaus2@washcoll.edu), Chestertown, MD, and **Heather M. Russell** and **Maisie Jann Newman**. *Relating Fox and face colorings of knot diagrams.* Preliminary report.

In 1956, Fox introduced the notion of coloring a knot diagram by assigning values to its arcs such that the values satisfy a particular system of congruence relations. Fox proved that the number of n-colorings of a diagram is an invariant. We introduce a new method of coloring a knot diagram, called face coloring, that assigns a value to each bounded face such that the values satisfy a different set of congruence relations. We have shown that the number of n-face colorings is an invariant. Fox and face coloring share many other similarities, and in this talk we will look at examples of both and explore the connections between them. (Received September 16, 2014)

1106-05-2475 **Timothy B Flowers*** (flowers@iup.edu) and **Shannon R Lockard** (shannon.lockard@bridgew.edu). *Properties of rational numbers on an $m-$ary tree.*

We recently introduced an $m-$ary tree with rational labels which is a generalization of the Calkin-Wilf tree. Similar to the connection between the Calkin-Wilf tree and the hyperbinary sequence, we showed that there is a relationship between this $m-$ary tree and hyper $m-$ary partitions. We used the structure of the tree to show several properties of the hyper $m-$ary integer partition sequence. In this talk, we will discuss additional properties of the $m-$ary tree, as well as how these properties relate to counting hyper $m-$ary partitions. (Received September 16, 2014)

1106-05-2502 **Lucas Kramer*** (lkramer@carroll.edu), Helena,, MT, and **Ryan R Martin** and **Michael Young**. *Forbidding diamonds in the Boolean lattice.*

The two dimensional Boolean lattice, also known as the diamond, consists of four distinct elements $A \subset B, C \subset D$. A Diamond-free family in the n-dimensional Boolean lattice is a family of sets that does not contain a copy of the Diamond.

There is an example of a diamond-free family in the n-dimensional Boolean lattice of size $(2 - o(1)) \cdot \binom{n}{\lfloor n/2 \rfloor}$. In this talk we will discuss how we found an upper bound of $(2.25 + o(1)) \cdot \binom{n}{\lfloor n/2 \rfloor}$. We also discuss that the so-called Lubell function is bounded by $2.25 + o(1)$, which is asymptotically the best possible under currently known approaches. (Received September 16, 2014)

1106-05-2507 **Michael N Crumley*** (crumley@findlay.edu), University of Findlay, 1000 N. Main St., Department of Mathematics, Findlay, OH 45840. *Generic Representation Theory of the Unipotent Upper Triangular Groups.*

We give a neat characterization of the d-dimensional representation theory of the Unipotent Upper Triangular groups U_n over a field k of characteristic $p > 0$, in the case where p is sufficiently larger than both n and d. Specifically, so long as $p \geq \max(n, 2d)$, every d-dimensional representation of U_n over k is a commuting product of individual representations, one for each of the representation's 'Frobenius layers', and each of which 'look like' a representation of U_n in characteristic zero (in the sense that both are given rise to, via the Baker-Campbell-Hausdorff formula, by a representation of the Lie algebra of U_n). This analogy between the 'generic' representation theory of U_n in positive characteristic and the representation theory of U_n^∞ in characteristic zero is in fact functorial, in the sense that the analogy is applicable to morphisms between representations as well. (Received September 16, 2014)

1106-05-2515 **Sarah R Bockting-Conrad*** (sarah.bockting@oberlin.edu). *Tridiagonal pairs of q-Racah type and the quantum group $U_q(\mathfrak{sl}_2)$.*

In this talk we explore a connection between tridiagonal pairs of q-Racah type and the quantum group $U_q(\mathfrak{sl}_2)$. Given a tridiagonal pair A, A^* on V that has q-Racah type, we introduce linear transformations $\psi : V \to V$, $K : V \to V$, and $B : V \to V$ which act on the split decompositions of V in an attractive way. Using ψ, K, B we obtain two $U_q(\mathfrak{sl}_2)$-module structures on V. For each of the $U_q(\mathfrak{sl}_2)$-module structures, we compute the action of the Casimir element on V. We show that these two actions agree. Using this fact, we express ψ as a rational function of $K^{\pm 1}, B^{\pm 1}$ in several ways. Eliminating ψ from these equations we find that K and B are related by a quadratic equation. (Received September 16, 2014)

1106-05-2529 **Jian Shen*** (js48@txstate.edu). *Destroying Cycles in m-free Circular Interval Digraphs.* Preliminary report.

A digraph G is m-free if G contains no (directed) cycles of length less than or equal to m. Let $\beta(G)$ be the minimum number of edges needed to be deleted from a digraph G to break all (directed) cycles of G. Let $\gamma(G)$ be the number of missing edges of G. In her Ph.D thesis (Princeton University, 2008), Sullivan conjectured that $\beta(G) \le \frac{2}{(m-2)(m+1)}\gamma(G)$ for all m-free digraphs G. In a special case when G is an m-free circular interval digraph, Sullivan proved that $\beta(G) \le \frac{1}{2(m-2)}\gamma(G)$. We report some initial result on this special case of the conjecture. This is joint work with three undergraduate students (James Dix of UT-Austin, Marcos Munoz of MIT, and Bobby Shen of MIT) in a 2014 summer undergraduate research program. (Received September 16, 2014)

1106-05-2547 **Steven Michael Senger*** (stevensenger@missouristate.edu). *Value sets of functions with finite domain, with applications to planar functions.*

By relating the number of images of a function with finite domain to a certain parameter, we obtain both an upper and lower bound for the image set. Even though the arguments are elementary, the bounds are, in some sense, best possible. These bounds are then applied in several contexts. In particular, we obtain the first non-trivial upper bound for the image set of a planar function over a finite field. (Received September 16, 2014)

1106-05-2553 **Elizabeth Beazley**, **Anna Bertiger*** (abertige@uwaterloo.ca) and **Kaisa Taipale**. *Cyclic Factorial Schur Polynomials and Geometry.* Preliminary report.

The Peterson isomorphism relates the homology of the affine Grassmannian and the quantum cohomology of flag varieties. Both sides carry rich symmetric function theories, but it's not trivial to see how they're related. This talk will discuss preliminary results toward relating "cyclic factorial Schur" polynomials, which the authors used to prove the equivariant rim hook rule for the quantum cohomology of the Grassmannian, with k-double Schur functions, which give the homology classes for the affine Grassmannian. The Peterson isomorphism says that the two must be related, but the symmetric function side is only slowly being discovered. (Received September 16, 2014)

1106-05-2564 **Torin Greenwood*** (toringr@math.upenn.edu). *Coefficients of Bivariate Analytic Functions with Algebraic Singularities.*

Flajolet and Odlyzko (1990) analyzed the coefficients of a class of univariate generating functions with algebraic singularities. These results have been extended to classes of multivariate generating functions by Gao and Richmond (1992) and Hwang (1996, 1998), in both instances by reducing the multivariate case to the univariate case. In this paper, we analyze the coefficients of a broader class of bivariate generating functions with algebraic singularities and smooth minimal critical points. Instead of reducing bivariate functions to the univariate case immediately, we apply the new multivariate analytic approaches outlined by Pemantle and Wilson (2013). The dominating contributions to the multivariate Cauchy integral formula are found by integrating over quasi-local cycles near the critical points of the function. Through explicit contour deformations near these critical points, we can manipulate the integrand until it is nearly the product of two univariate functions, leaving us with easily computable one-dimensional integrals. (Received September 16, 2014)

1106-05-2567 **Hang M Do*** (hdo@linfield.edu), **Brent Moran** (brent.moran@ucdenver.edu) and **Timothy Singer** (tsinger@linfield.edu). *1-Relaxed Modular Edge-Sum Labeling.*

We introduce a new graph labeling and derive a game on graphs called the *1-relaxed modular edge-sum labeling game*. Given a graph G and a natural number n, we define a labeling by assigning to each edge a number from $\{1,\ldots,n\}$ and assign a corresponding label for each vertex u by the sum of the labels of the edges incident to u, computing this sum modulo n. Similar to the chromatic number, we define $\Lambda(G)$ for a graph G as the smallest n such that G has a proper labeling. We provide bounds for $\Lambda(G)$ for various classes of graphs. Motivated by competitive graph coloring, we define a game on G using modular edge-sum labeling and determine the chromatic game number for various classes of graphs. We will emphasize some characteristics that distinguish this labeling from traditional vertex coloring. (Received September 16, 2014)

1106-05-2600 **Risto Atanasov*** (ratanasov@email.wcu.edu), Department of Mathematics and Computer Scienc, Western Carolina University, Cullowhee, NC 28723, and **Mark Budden**, **Joshua Lambert**, **Kyle Murphy** and **Andrew Penland**. *On Certain Induced Subgraphs of Paley Graphs.*

Since the advent of Ramsey Theory in the 1930's, Paley Graphs have played an important role in the determination of lower bounds for diagonal Ramsey numbers due to their randomness. The construction of Paley graphs (whose vertices are identified with finite field $\mathbb{F}_q$) leads to several natural induced subgraphs worth considering. We consider the subgraphs induced on the squares $\mathbb{F}_q^{\times 2}$ and the subgraphs induced on $\mathbb{F}_q^{\times} - \mathbb{F}_q^{\times 2}$. We describe their basic properties, demonstrate their utility in simplifying the determination of clique/independence numbers for Paley graphs, and address the determination of their diameters. (Received September 16, 2014)

1106-05-2605 **Carsten L Peterson*** (carsten.peterson@yale.edu). *Some Results on Two-Lifts of Graphs.* Preliminary report.

Let $\lambda(G)$ be the largest modulus of all non-trivial eigenvalues of the adjacency matrix of a d-regular graph G. A d-regular graph with $\lambda(G) \leq 2\sqrt{d-1}$ is called Ramanujan, which is an extremal property of d-regular graphs. Marcus, Spielman and Srivastava recently proved the existence of bipartite Ramanujan graphs of all degrees using what they call the method of interlacing families of polynomials. Their proof depended on performing 2-lifts of graphs based on a signing of the edges, and that the eigenvalues of bipartite graphs are symmetrically distributed. Motivated by the goal of proving the existence of non-bipartite Ramanujan graphs of all degrees, we examine 2-lifts of graphs. Notably, we introduce a class of signings of lifted graphs which give symmetrically distributed eigenvalues (relatively self-complementary signings), combinatorially characterize the coefficients of the expected characteristic polynomial of this class of signings, give a recursive method for calculating the matching polynomial of the 2-lift of a graph, as well as an explicit method for performing a Ramanujan 2-lift of the complete graph for all n. (Received September 16, 2014)

1106-05-2616 **Jennifer K. Aust*** (jka0006@auburn.edu). *Bounded Complete Embedding Graphs.*

A graph G is a *bounded complete embedding graph* if and only if, for some positive integer b, every G-design of order n can be embedded in a G-design of order $n+x$, for some positive integer x such that $1 \leq x \leq b$. We give some necessary conditions for a graph G to be a bounded complete embedding graph, and present some infinite classes of such graphs. (Received September 16, 2014)

1106-05-2647 **Masaki Ikeda*** (iked0565@vandals.uidaho.edu), 709 S Deakin St, Moscow, ID 83844. *Enumeration of permutations in Av*$(52341, 53241, 52431, 35142, 42513, 351624)$. Preliminary report.

Certain classes of Schubert varieties are indexed by permutations in some pattern avoidance classes. In this talk, I present the concept of permutation avoidance, and progress towards obtaining the generating function of the class $\mathcal{A}' = \mathrm{Av}(52341, 53241, 52431, 35142, 42513, 351624)$ whose permutations index Schubert varieties that are local complete intersections. (Received September 16, 2014)

1106-05-2696 **Alexander Garver** (garv0102@math.umn.edu), University of Minnesota, and **Jacob P. Matherne*** (jmath34@tigers.lsu.edu), Louisiana State University. *Linear Extensions and Exceptional Sequences.* Preliminary report.

A classical problem in combinatorics is to count the linear extensions of a poset. We consider a class of posets that index certain equivalence classes of complete exceptional sequences of modules over the path algebra of the linearly ordered quiver. It turns out that there is a bijection between such equivalent complete exceptional sequences and the linear extensions of the corresponding poset. We describe a method for counting the linear extensions of these posets. (Received September 16, 2014)

1106-05-2707 **James M Shook*** (james.shook@nist.gov) and **Isabel Beichl** (isabel.beichl@nist.gov). *Matrix Scaling: A New Heuristic for the Feedback Vertex Set Problem.*

For a digraph G, a set $F \subseteq V(G)$ is said to be a feedback vertex set (FVS) if $G - F$ is acyclic. The problem of finding a smallest FVS is NP-hard. We present a matrix scaling technique for finding feedback vertex sets in un-weighted directed graphs that runs in $O(|F| \log(|V|)|V|^2)$ time. Our technique is empirically shown to produce smaller feedback vertex sets than other known heuristics. (Received September 16, 2014)

1106-05-2711 **Elizabeth Drellich*** (drellich@math.umass.edu), **Frances Black** and **Julianna Tymoczko**. *Valid Plane Trees: Combinatorial Models for RNA Structures with Watson-Crick Pairs.*

A valid plane tree is a word P of length $2n$ paired with a plane tree S with n edges such that S describes a perfect non-crossing matching of the letters of P. This object is inspired by molecular biology: RNA is a word in the letters A, U, G, C that folds onto itself. The basic plane tree model of this folding introduced by Heitsch presents the plane tree S, we consider whether the word P can fold into that shape. We show that the two types of valid local moves on valid plane trees results in a connected graph, and prove that the graph has a unique sink (source) under type 1 (2) valid local moves. This unique sink (source) is the valid plane tree formed by the greedy algorithm. (Received September 16, 2014)

1106-05-2715 **Matthew Moynihan*** (mmoynihan@wooster.edu). *On Permutation Statistics and Algebras.* Preliminary report.

Every permutation statistic describes a set partition of the symmetric group. Turning the blocks of a set partition into formal sums of permutations sometimes produces a basis for an algebra. While many common permutation statistics produce such a result (descent number, descent set, peak set), there are equally common permutation statistics which fail to produce this elegant result (major index, cyclic descent set). In this talk, we explore some of these "successful" permutation statistics and look at their various extensions. (Received September 16, 2014)

1106-05-2745 **Samuel Clearman*** (sam@samclearman.com), Dept of Mathematics, 14 E. Packer Ave, Bethelehem, PA 18015. *Combinatorial evaluation of Hecke algebra characters.*

Iwahori-Hecke algebras are deformation algebras of Coxeter groups. Their representation theory has been found to have connections to topics as diverse as quantum groups, total positivity, and chromatic polynomials. We give combinatorial formulae for the evaluation of certain characters on Kazhdan-Lusztig basis elements and applications. (Received September 16, 2014)

1106-05-2758 **Nathan Reff*** (nreff@brockport.edu), Department of Mathematics, The College at Brockport, State University of New York, Brockport, NY 14420. *Intersection graphs of oriented hypergraphs and their matrices.* Preliminary report.

An oriented hypergraph is a hypergraph where each vertex-edge incidence is given a label of +1 or -1. The intersection graph of an oriented hypergraph generalizes the line graph of a signed graph. An arbitrary simple signed graph is shown to be the intersection graph of infinitely many k-uniform linear oriented hypergraphs. The intersection graph and the dual of an oriented hypergraph are used to generalize some fundamental matrix relationships known for graphs and signed graphs. Eigenvalues of the adjacency and Laplacian matrices associated to an oriented hypergraph, its dual, and intersection graph are also studied. (Received September 16, 2014)

1106-05-2808 **Mary Allison** and **Bryan L Shader*** (bshader@uwyo.edu), 1000 E. University Ave, Math Department 3036, University of Wyoming, Laramie, WY 82071. *The minimum Kemeny constant problem.*

Let G is a connected graph on vertices, $1, 2, \ldots, n$. We study a new optimization problem over the family Mark(G) of all $n \times n$, symmetric, stochastic matrices $A = [a_{ij}]$, where the graph of A is an edge subgraph of G. More precisely, $a_{ij} \neq 0$ only if $i = j$, or $i \neq j$ and i is adjacent to j in G.

Boyd, Diaconis and Xiao in 2003 initiated the study of the Fastest Mixing Markov Chain on G, which corresponds to asking for the $A \in$ Mark(G) whose second largest eigenvalue modulus (SLEM) is smallest. It is known that the SLEM of A governs the rate of convergence of the corresponding Markov chain C.

The Kemeny constant, $K(A)$, of A is the expected number of steps for the chain C to start at a randomly selected state and first enter another randomly selected state. It provides some rough information about the short-term behavior of the Markov chain. If the graph of A is disconnected, then Kemeny constant is taken to be ∞.

In this talk we study the problem of determining the inf of $K(A)$ over all $A \in \mathrm{Mark}(G)$. General results about properties of optimizing matrices are proven, and the inf is determined for several families of graphs. (Received September 16, 2014)

1106-05-2853 **Svante Janson** and **Brian Nakamura***, bnaka@dimacs.rutgers.edu, and **Doron Zeilberger**. *On the Asymptotic Statistics of the Number of Occurrences of Multiple Permutation Patterns.*

In this talk, we will discuss statistical properties of the random variables $X_\sigma(\pi)$, the number of occurrences of the pattern σ in the permutation π. We present two contrasting approaches to this problem: traditional probability theory and the "less traditional" computational approach. Through the perspective of the first one, we prove that for any pair of patterns σ and τ, the random variables X_σ and X_τ are jointly asymptotically normal (when the permutation is chosen from S_n). From the other perspective, we develop algorithms that can show asymptotic normality and joint asymptotic normality (up to a point) and derive explicit formulas for quite a few moments and mixed moments empirically, yet rigorously. The computational approach can also be extended to the case where permutations are drawn from a set of pattern avoiders to produce many empirical moments and mixed moments. This data suggests that some random variables are not asymptotically normal in this setting. (Received September 16, 2014)

1106-05-2873 **Iwan Duursma*** (duursma@math.uiuc.edu). *Coding theory for distributed storage and networks.*

We present new lower bounds for the parameters of a distributed storage system. In a (n,k,d) distributed storage system a file is stored on n servers such that it can be recovered from any combination of k servers. If a server fails it can be rebuilt by retrieving information from any combination of d other servers. As an example, four bits x,y,z,t can be stored as four two-bit pairs (x,z+t), (y,t+x), (z,x+y), (t,y+z). The four bits can be reconstructed from any two pairs. And any pair can be rebuilt after receiving one bit from each of the other servers, e.g. the pair (x,z+t) from the three bits y, x+y, t+y+z. We also address the related protocol of communicating over a network with multiple nodes and some of the mathematical problems that arise. (Received September 16, 2014)

06 ► Order, lattices, ordered algebraic structures

1106-06-206 **Tristan M Bice*** (tristan.bice@gmail.com) and **Charles A Akemann**. *Hereditary C*-Subalgebra Lattices.*

Hereditary C*-subalgebras are often likened to the open subsets of topological spaces. Despite this indication of its importance, comparatively little is known about the hereditary C*-subalgebra lattice $\mathcal{H}(A)$ and various special elements that lie within it. Our recent research aims to rectify this by relating the order structure of $\mathcal{H}(A)$ to the algebraic structure of A in various ways. For example, we characterize ideals as $\wedge$-distributive elements, which yields the quantale structure of $\mathcal{H}(A)$ purely from its lattice structure. We also show how *-annihilators are separative and how this allows for C*-algebra type decompositions that are completely consistent with the original von Neumann algebra type decompositions. (Received August 10, 2014)

1106-06-1173 **Jean-Francois Biasse*** (jbiasse@uwaterloo.ca), University of Waterloo, 200 University Ave. West, Waterloo, Ontario N2L 3G1, Canada. *Ideal lattice problems and applications to cryptography.*

Ideals in the ring of integers of a number field have a lattice structure, and they are considered for the design of many lattice-based cryptosystems. These rely on the hardness of finding a short vector in a lattice of large dimension presented by an arbitrary basis. The main appeal of these schemes is their potential for quantum resistance and homomorphic encryption, which are two major challenges inpublic-key cryptography.

Using lattices that are embedded in a number field of large degree is interesting for efficiency reasons, but it seems that the surrounding algebraic structure may also be used to design attacks. In particular, in many cases the ideals are principal, and the knowledge of a short generator is enough to break the cryptosystem (finding some arbitrary generator is called the principal ideal problem).

In this talk, we present recent developments in the resolution of the principal ideal problem relying on new subexponential methods for computing the class group and the unit group of a large degree number field, which have fundamental applications in number theory. We will also present work in progress on an algorithm for finding a short generator of a principal ideal which directly applies to the cryptanalysis of ideal lattice-based cryptosystems. (Received September 11, 2014)

1106-06-1175 **Bernd S. W. Schroeder*** (bernd.schroeder@usm.edu), Department of Mathematics, The University of Southern Mississippi, 118 College Drive, #5045, Hattiesburg, MS 39406.
Every Order-Preserving Self-Map of the L^p Unit Ball has a Fixed Point.

In this talk, we will prove that every order-preserving self-map of the unit ball in L^p has a fixed point. The proof is surprisingly simple, as we merely need to establish that the L^p unit ball is chain-complete and dismantlable (via comparative retractions).

To date, the use of order-theoretical techniques in L^p spaces has been limited to many results and examples that employ the usual Abian-Brown iteration: For an order-preserving operator T, if there is a function f with $f \leq Tf$, then (transfinite) iteration of the operator either terminates in a fixed point, or, there is no fixed point above f.

Despite its simplicity, the result discussed in this talk is order-theoretically more subtle than the Abian-Brown iteration. In some ways, the author considers the result as a "theorem in need for an application." (Received September 11, 2014)

1106-06-1876 **Comlan de Souza*** (csouza@csufresno.edu). *Characterization of self dual lattices in $\mathbb{R}, \mathbb{R}^2$, and $\mathbb{R}^3$.*

Consider the linearly independent sets of real n (column) vectors $a_1, \ldots, a_n$ and the lattice generated by these vectors

$$\mathcal{L}_A := \left\{ \sum_{k=1}^{n} m_k \; a_k : m_1, \ldots, m_n \in \mathbb{Z} \right\}$$

where A is the matrix formed by these column vectors. The lattice $\mathcal{L}_{A^{-T}}$ generated by vectors biorthogonal to $a_1, \ldots, a_n$ is said to be the dual of the lattice $\mathcal{L}_A$. Moreover $\mathcal{L}_A$ is said to be self dual if and only if

$$(A^{-T})^{-1} A = A^T A$$

is a matrix of integers with determinant ± 1. We will show by an ad-hoc method, that the only self dual lattices in $\mathbb{R}, \mathbb{R}^2, \mathbb{R}^3$ are rotations of $\mathbb{Z}, \mathbb{Z} \times \mathbb{Z}$, and $\mathbb{Z} \times \mathbb{Z} \times \mathbb{Z}$. (Received September 15, 2014)

1106-06-2152 **David Hemminger*** (david.hemminger@duke.edu), **Aaron Landesman** (aaronlandesman@gmail.com) and **Zijian Yao** (zijian_yao@brown.edu). *Peckness of Edge Posets.* Preliminary report.

For P a graded poset we define a new graded poset, called its edge poset $\mathcal{E}(P)$, whose elements are the edges in the Hasse diagram of P. We then consider the structure of $\mathcal{E}(P)$. In particular, we conjecture that $\mathcal{E}(B_n/G)$ is Peck for any group G acting on the boolean algebra B_n, and we define a large class of "common cover transitive" group actions for which we answer this conjecture in the affirmative. (Received September 15, 2014)

1106-06-2310 **Jillian E Parker*** (jep030@shsu.edu) and **Monica Elizabeth Gorman** (mgorman4@nd.edu). *Omega Values of the Generators of Certain Primitive Numerical Monoids.*

Let M be a commutative, cancellative, atomic monoid with units $M^\times$ and atoms (or irreducibles) $\mathcal{A}(M)$. For $x \in M \setminus M^\times$, we define the omega function by $\omega(x) = n$ if n is the smallest positive integer such that if $x \mid a_1 \ldots a_t$ with each $a_i \in \mathcal{A}(M)$, then there is a $T \subseteq \{1, \ldots, t\}$ with $|T| \leq n$ such that $x \mid \Pi_{k \in T} a_k$. Moreover, the ω-function measures how close to prime an element is. We will conjecture simple formulas for determining these omega values of a primitive numerical monoid in any embedding dimension, where the set S is generated by a generalized arithmetic sequence of the form $\langle a, ah+d, ah+2d, \ldots, ah+xd \rangle$ where $a,\ d,\ h$ and, x are positive integers and $gcd(a, d) = 1$. We show by applying a theroem by Omidali and Rahmati that these results are valid and enhance the understanding of generators of certain primitive numerical monoids. Our research was supervised by Dr. Scott Chapman (Sam Houston State University) and funded by NSF grant DMS-1262897. (Received September 16, 2014)

08 ► General algebraic systems

1106-08-466 **Thomas Barron**, **Christopher ONeill*** (coneill@math.tamu.edu) and **Roberto Pelayo**. *The Set of Elasticities in Numerical Monoids.*

In an atomic commutative monoid, the elasticity of an element provides a coarse measure of its non-unique factorizations by comparing the largest and smallest values in its set of factorization lengths (called its length set). Recent work examines the set of length sets as a factorization invariant for numerical monoids generated by arithmetic sequence (called arithmetical numerical monoids), and shows in particular that two such monoids can have the same set of length sets. In this talk, we present results from an undergraduate research project showing that the set of length sets for any arithmetical numerical monoid can be completely recovered from its set of elasticities. We also demonstrate the stark contrast between the set of length sets, which is often very large and hard to compute, with the set of elasticities, by showing that for more general numerical monoids, the latter is determined by only finitely many values. (Received August 29, 2014)

1106-08-768 **Christopher ONeill*** (musicman3320@gmail.com), **Vadim Ponomarenko**, **Reuben Tate** and **Gautam Webb**. *Catenary Degrees of Elements in Numerical Monoids.*

Nonunique factorization in commutative monoids is often studied through the use of factorization invariants. One such invariant, called the catenary degree, measures the distance between factorizations within a given monoid, and can be computed using a graph theoretic construction. In this talk, we present results from an undergraduate research project involving the catenary degree in additive submonoids of the natural numbers. (Received September 06, 2014)

1106-08-2224 **Hannah Vogel*** (hannah.vogel@uni-graz.at). *Asymptotic triangulations and Coxeter transformations of the annulus.* Preliminary report.

Asymptotic triangulations can be viewed as limits of triangulations under the action of the mapping class group. We construct an alternative method of obtaining these asymptotic triangulations using Coxeter transformations. This provides us with an algebraic and combinatorial framework for studying these limits via the associated quivers and root systems. (Received September 16, 2014)

1106-08-2588 **McCleary Philbin*** (mphilbin@smith.edu), **Lindsay Swift**, **Alison Tammaro**, **Julianna Tymoczko**, **Danielle Williams** and **Nealy Bowden**. *Generalized splines and quotient rings.* Preliminary report.

Consider a combinatorial graph each of whose edges is labeled with an integer. A spline is a way to label the vertices so that the difference between each pair of adjacent vertices is a multiple of the edge's label.

Splines originally developed in engineering applications, in order to model complex shapes (like boats or cars) more simply while developing designs. One way to do this is choose key points on the object and attach thin strips of wood—called splines—between those points. Mathematical splines are now essential to many applied fields, including computer graphics, numerical algorithms, and PDEs. Billera pioneered algebraic splines, which brought tools from homological and commutative algebra to bear on the study of splines. More recently, work of Gilbert-Polster-Tymoczko, Handschy-Melnick-Reinders, and Bowden-Hagen-King-Reinders generalized splines even further.

In this talk, we describe new work on generalized splines. We focus on the case when edges are labeled by elements of a quotient ring. Time permitting, we will describe some applications to Schubert calculus. (Received September 16, 2014)

11 ► Number theory

1106-11-19 **Henri Darmon*** (darmon@math.mcgill.ca), McGill University,805 Sherbrooke St W, Montreal QC Canada. *Elliptic curves and explicit class field theory.* Preliminary report.

The values of the exponential function $e^{2\pi iz}$ and of the modular function $j(z)$ (at rational and quadratic imaginary arguments, respectively) give explicit generators for essentially all abelian extensions of the field of rational numbers and of quadratic imaginary fields. The associated theories of cyclotomic fields and of complex multiplication are quite rich and were actively pursued throughout the 19th century. Kronecker's "Jugendtraum", raised again by Hilbert as the twelfth in his celebrated list of open problems for the 20th century, seeks to extend these theories to base fields other than the rationals or quadratic imaginary fields. More than a hundred years later, Hilbert's 12th problem is still largely open. This lecture shall describe this question and its possible connections to the construction of rational points on elliptic curves, tying in with another fundamental open problem in number theory: the celebrated Birch and Swinnerton-Dyer conjecture. (Received November 3, 2014)

1106-11-58 **Steven J Miller*** (sjm1@williams.edu), 18 Hoxsey Street, Williams College, Williamstown, MA 01267, and **Francesco Cellarosi**, **Doug Hensley** and **Jake Wellens**. *Continued Fraction Digit Averages and Maclaurin's Inequalities.*

Khinchin proved that for almost all real α the geometric mean of the first n digits $a_i(\alpha)$ in its continued fraction expansion converges to $K = 2.68545\dots$ (Khinchin's constant) as $n \to \infty$. On the other hand, for almost all α the arithmetic mean of the first n continued fraction digits $a_i(\alpha)$ approaches infinity as $n \to \infty$. There is a sequence of refinements of the AM-GM inequality, Maclaurin's inequalities, relating the $1/k^{\text{th}}$ powers of the k^{th} elementary symmetric means of n numbers for $1 \le k \le n$. On the left end $(k = n)$ we have the geometric and on the right end ($k = 1$) we have the arithmetic mean. We analyze the means of continued fraction digits of a typical real number in the limit as one moves $f(n)$ steps away from either extreme. We prove sufficient conditions on $f(n)$ to ensure divergence when one moves $f(n)$ steps away from the arithmetic mean and convergence when one moves $f(n)$ steps away from the geometric mean. For typical α we conjecture the behavior for $f(n) = cn$, $0 < c < 1$, and prove bounds towards these claims. We also study the limiting behavior of such means for quadratic irrationals, providing rigorous results and numerically supported conjectures. (Received June 04, 2014)

1106-11-92 **Ricardo Conceicao***, 100 Hamill st, Oxforg, GA 30054, and **Herivelto Borges**. *Minimal value set polynomials and a generalization of the Hermitian curve.*

We use minimal value set polynomials in the construction of curves over $\mathbb{F}_q$ that generalize the hermitian curve. We compute the genus g, the number N of rational points and, in some cases, the Weierstrass semigroup at the point at infinity of such curves. We show that they provide new examples of Castle curves curves and improve on a previous example of Garcia-Stichtenoth of curves with large ratio N/g. Due to its many nice arithmetic and geometric properties, we expect that such curves are suitable to the construction of algebro-geometric codes with nice parameters. (Received July 08, 2014)

1106-11-125 **Larry J. Gerstein*** (gerstein@math.ucsb.edu), Department of Mathematics, University of California, Santa Barbara, CA 93106-3080. *Integral quadratic forms and graph isomorphism.* Preliminary report.

Let G_1 and G_2 be undirected graphs with adjacency matrices A_1 and A_2. Then G_1 and G_2 are isomorphic if and only if there is a permutation matrix P such that $A_2 = {}^tPA_1P$. On the other hand, if A_1 and A_2 are viewed as the Gram matrices of integral quadratic forms q_1 and q_2, then q_1 and q_2 are equivalent quadratic forms if and only if there is a *unimodular* matrix P such that $A_2 = {}^tPA_1P$. The talk will consider the application of the theory of integral quadratic forms to the graph isomorphism problem. (Received July 23, 2014)

1106-11-180 **SoYoung Choi** and **Bo-Hae Im***, Department of Mathematics, Chung-Ang University, Seoul, 156-756, South Korea. *The zeros of certain weakly holomorphic Drinfeld modular forms and quasi-modular forms.*

Duke and Jenkins constructed a canonical basis for the space of weakly holomorphic modular forms for $SL_2(Z)$ and investigated the zeros of the basis elements. In this talk, we give an analogy in the Drinfeld setting of the result given by Duke and Jenkins. Also we give a location of zeros of certain quasi-modular forms for $\Gamma_0^+(N)$. This is a joint work with SoYoung Choi. (Received August 05, 2014)

1106-11-181 **Kestutis Cesnavicius***, University of California, Berkeley, CA 94720-3840. *p-Selmer growth in extensions of degree p.*

There is a known analogy between growth questions for class groups and for Selmer groups. If p is a prime, then the p-torsion of the class group grows unboundedly in $\mathbb{Z}/p\mathbb{Z}$-extensions of a fixed number field K, so one expects the same for the p-Selmer group of a nonzero abelian variety over K. This Selmer group analogue is known in special cases, and we prove it in general along with its extension to arbitrary isogenies over global fields (excluding some $p = \mathrm{char}K$ cases). The key tool is a version of the Cassels–Poitou–Tate sequence, which we extend to arbitrary global fields. (Received August 05, 2014)

1106-11-205 **Charles L Samuels*** (clsamuels@okcu.edu), Oklahoma City University, Department of Mathematics, 2501 N. Blackwelder, Oklahoma City, OK 73106. *Using trees to find optimal factorizations of numbers.*

Dubickas and Smyth introduced the metric Mahler measure as a method of examining questions related to Lehmer's problem. A slight generalization of their work allows us to study factorizations of algebraic numbers having certain extremal properties, called optimal factorizations. In this talk, we describe a method using trees which enables us to search for these optimal factorizations. This work is joint with T.J. Strunk. (Received August 10, 2014)

1106-11-252 **Hui June Zhu*** (hjzhu@math.buffalo.edu), Department Of Mathematics, State University of New York at Buffalo, Buffalo, NY 14260. *Almost generic p-divisibility bound.*

The well-known theorem of Ax and Katz gives a p-divisibility bound for the number of rational points on an algebraic variety V over a finite field of characteristic p in terms of the degree and number of variables of defining polynomials of V. We give a p-divisibility bound in terms of the supporting coefficient sets of the algebraic variety that refines and strengthens Ax-Katz bound; given prescribed sets of nonzero coefficient supports, suppose its combinatorial conditional number is nonzero, we show that any algebraic variety supported on these sets over the rationals achieves our p-divisibility bound at a set of primes p of positive density. (Received August 15, 2014)

1106-11-255 **Barry R. Smith*** (barsmith@lvc.edu), 101 N. College Dr., Annville, PA 17003.
End-symmetric continued fractions and binary quadratic forms. Preliminary report.

With each finite sequence of positive integers, we associate a positive integer, built from continued fractions, that we call the alternant of the sequence. There are only finitely many sequences with a given alternant value, and we put this fact to three uses. 1) We show that the sequence of quotients of the continued fraction expansion of a rational number $\alpha/\beta > 1$ when β satisfies the congruence $x^2 + nx \pm 1 \equiv 0 \pmod{\alpha}$ must have one of a finite number of "asymmetry types", generalizing the old theorem that the sequence of quotients is symmetric precisely when $\beta^2 \equiv \pm 1 \pmod{\alpha}$. 2) We introduce a bijection between sequences with alternant n and the finite set of Zagier-reduced binary quadratic forms with discriminant $n^2 \pm 4$ and show that the Zagier reduction algorithm corresponds to a simple operation on the corresponding sequences. 3) We craft an algorithm, based on the Euclidean algorithm, for producing the representations of a positive integer n by an indefinite form with discriminant of the form $n^2 \pm 4$. (Received August 21, 2014)

1106-11-296 **Shaun Cooper** and **Dongxi Ye*** (lawrencefrommath@gmail.com), Department of Mathematics, University of Wisconsin, 480 Lincoln Drive, Madison, WI 53706. *The Rogers-Ramanujan continued fraction and its level* 13 *analogue.*

One of the properties of the Rogers-Ramanujan continued fraction is its representation as an infinite product given by

$$r(q) = q^{1/5} \prod_{j=1}^{\infty} (1 - q^j)^{\left(\frac{j}{5}\right)}$$

where $\left(\frac{j}{p}\right)$ is the Legendre symbol. In this work we study the level 13 function

$$R(q) = q \prod_{j=1}^{\infty} (1 - q^j)^{\left(\frac{j}{13}\right)}$$

and establish many properties analogous to those for the fifth power of the Rogers-Ramanujan continued fraction. (Received August 20, 2014)

1106-11-310 **aBa Mbirika*** (mbirika@uwec.edu). *Finding square patches of invisible lattice points using quasiprime matrices.*

It is well known that approximately 40 percent of the integer lattice is hidden from view from the origin. Many have studied a variety of problems involving lattice point visibility, in particular, searching for patterns in this 40 percent of invisible points. One such pattern is a square patch, which we call a hidden forest. It is known that there exists arbitrarily large hidden forests in the integer lattice. However, the methods up to now have only been able to locate hidden forests very far from the origin using the Chinese Remainder Theorem (CRT) on the rows and columns of prime matrices. We introduce the concept of quasiprime matrices and utilize a variety of computational and theoretical techniques to find much closer hidden forests than have been found up to now. We conjecture that every hidden forest can be found via a quasiprime matrix and the CRT-algorithm. (Received August 20, 2014)

1106-11-320 **Bianca A Thompson*** (bat7@hawaii.edu). *Rational maps with $\mathbb{Q}_p$ critical points.* Preliminary report.

In prior work by Eremenko and Gabrielov it is shown that if all critical points of a rational function ϕ are real, then ϕ is equivalent to a real rational function. We can reframe the question in the local field $\mathbb{Q}_p$. We prove a rational map *phi* of degree $d \geq 2$ with exactly 2 distinct critical points in $\mathbb{Q}_p$ is equivalent to a $\mathbb{Q}_p-$rational function. Similarly, if ϕ is a degree 3 map with 4 critical points in $\mathbb{Q}_p$ it is equivalent to a $\mathbb{Q}_p-$rational function. (Received August 21, 2014)

1106-11-321 **Xiaoyu He*** (xiaoyuhe@college.harvard.edu), 282 Eliot House Mail Center, Cambridge, MA 02138. *Geometric Progression Free Sequences with Small Gaps.*

In this talk we prove the existence of geometric progression free sequences of natural numbers with small gaps, partially answering a question posed originally by Beiglböck et al. Using probabilistic methods we prove the existence of a sequence T not containing any 6-term geometric progressions with gaps of size O(exp(C log x/ loglog x)). Our approach requires certain elementary bounds on sums of arithmetic functions in short intervals. We will touch on related problems about arithmetic-progression free sequences and multiplicative number theory. (Received August 21, 2014)

1106-11-341 **James A Sellers*** (sellersj@psu.edu), Department of Mathematics, 104 McAllister Building, University Park, PA 16802. *Arithmetic Properties of Andrews' Singular Overpartitions.*

In a very recent work, G. E. Andrews defined the combinatorial objects which he called *singular overpartitions* with the goal of presenting a general theorem for overpartitions which is analogous to theorems of Rogers–Ramanujan type for ordinary partitions with restricted successive ranks. As a small part of his work, Andrews noted two congruences modulo 3 which followed from elementary generating function manipulations. In this talk, we show that Andrews' results modulo 3 are two examples of an infinite family of congruences modulo 3 which hold for that particular function. Time permitting, we will also expand the consideration of such arithmetic properties to other functions which are part of Andrews' framework for singular overpartitions. This is joint work with Shi-Chao Chen and Michael D. Hirschhorn. (Received August 23, 2014)

1106-11-385 **Krishnaswami Alladi*** (alladik@ufl.edu), Department of Mathematics, University of Florida, Gainesville, FL 32611. *A multi-dimensional extension of Sylvester's identity.*

In 1882 Sylvester obtained a significant refinement of Euler's celebrated pentagonal numbers theorem by combinatorial means. Subsequently Cayley produced a q-hypergeometric proof. We now obtain a multi-dimensional extension of Sylvester's identity by extending his combinatorial method. We then provide a q-hypergeometric proof by extending Cayley's method. (Received August 26, 2014)

1106-11-392 **Qingquan Wu*** (qingquan.wu@tamiu.edu), 5201 University Blvd, Laredo, TX 78041. *The ramification group filtration on certain function field extensions.*

We investigate the ramification group filtration of Galois extension of function fields, if the Galois group satisfies a certain intersection property. Such a property holds for all finite groups if every Sylow p-subgroup of them is elementary abelian. Note that such groups could be non-abelian. We show how the problem can be reduced to the totally wild ramified case on an p- extension. Our methodology is based on an intimate relationship between the ramification groups of the field extension and the ones of all degree p sub-extensions. Not only do we confirm the Hasse-Arf property holds in this setting, we also prove that the Hasse-Arf divisibility result is the best possible by explicit calculations of the divisors, which are expressed in terms of the different exponents of all those degree p sub-extensions.

This work is in cooperation with Jeffery A. Castañeda as his master thesis. (Received August 26, 2014)

1106-11-403 **Taisong Jing*** (tuj10@psu.edu), Department of Mathematics, The Pennsylvania State University, 107 McAllister Building, University Park, PA 16802. *The reductions of finite subgroups of CM abelian varieties.*

Let L be a CM field. CM abelian schemes with L-action over a (0,p) mixed characteristic complete discrete valuation ring with algebraically closed residue field are classified up to L-linear isogeny by the p-adic CM type. If we further require the full ring of integers $\mathcal{O}_L$ to act on the abelian scheme, then the p-adic CM type determines the L-linear isomorphic type. Under certain assumptions on such CM abelian schemes, we give a description on the reductions of their finite locally free subgroup schemes. This work has applications in the CM lifting problem for abelian varieties. (Received August 27, 2014)

1106-11-426 **Joseph Stahl*** (josephmichaelstahl@gmail.com), **David Mehrle** (dmehrle@cmu.edu), **Tomer Reiter** (treiter@andrew.cmu.edu), **Dylan Yott** (dtyott@gmail.com) and **Steven Miller** (sjm1@williams.edu). *Newman's conjecture for function field L-functions.*

De Bruijn and Newman introduced a deformation of the completed Riemann zeta function $\zeta(s)$, and proved there is a real constant Λ which encodes the movement of the nontrivial zeros of $\zeta(s)$ under the deformation. The Riemann hypothesis is equivalent to the assertion that $\Lambda \leq 0$. Newman, however, conjectured that $\Lambda \geq 0$.

Andrade, Chang, and Miller extended the machinery of Newman and Polya to L-functions for function fields $\mathbb{F}_q(T)$. In this setting we must consider a modified Newman's conjecture: $\sup_{f\in\mathcal{F}} \Lambda_f \geq 0$, for $\mathcal{F}$ a family of L-functions. We prove this modified Newman's conjecture for several families of L-functions. In contrast with previous work, we exhibit specific L-functions for which $\Lambda = 0$, and thereby prove a stronger statement: $\max_{L\in\mathcal{F}} \Lambda_L = 0$. To prove this, we show a certain L-function must have a double root, which implies $\Lambda = 0$. For a different family, we construct particular elliptic curves E with $p+1$ points over $\mathbb{F}_p$ and use the Weil conjectures to conclude $\#E(\mathbb{F}_{p^{2n}})$ attains the bound over $\mathbb{F}_{p^{2n}}$. This tells us that the associated L-function satisfies $\Lambda = 0$. (Received August 27, 2014)

1106-11-427 **David Mehrle*** (dmehrle@cmu.edu), **Tomer Reiter** (treiter@andrew.cmu.edu), **Joseph Stahl** (josephmichaelstahl@gmail.com), **Dylan Yott** (dtyott@gmail.com) and **Steven Miller** (sjm1@williams.edu). *A Family of Rank 6 Elliptic Curves over Number Fields.*

We construct a family of elliptic curves over a number field K, and prove that when $K/\mathbb{Q}$ is Galois, each curve has rank six. Unlike most constructions, which only bound the rank, we find the rank exactly. By evaluating Legendre sums, we determine equations for curves $\mathcal{E}$ with $A_\mathfrak{p}(\mathcal{E}) = -6$. Applying a theorem of Rosen and Silverman, we show that the rank is $-A_\mathfrak{p}(\mathcal{E})$. We obtain in this manner not only infinitely many elliptic curves over K, but also infinitely many elliptic surfaces, i.e., elliptic curves over the function field $K(T)$. Additionally, we hypothesize that curves definedanalogously over non-Galois extensions $L/\mathbb{Q}$ also have rank six, which we prove in several cases, and determine bounds for all other cases. Moreover, we prove that when $K = \mathbb{Q}$, if there are any points of finite order in$\mathcal{E}(\mathbb{Q})$, they must have order three. However, we are able to modify our construction to find a family of curves with group $\mathcal{E}(\mathbb{Q}) = \mathbb{Z}^2 \oplus \mathbb{Z}/2\mathbb{Z}$. This generalizes work of Arms, Lozano-Robledo, and Miller, which only dealt with families over $\mathbb{Q}$. (Received August 27, 2014)

1106-11-445 **Edray Herber Goins*** (egoins@math.purdue.edu), Mathematical Sciences Building, 150 North University Street, West Lafayette, IN 47907, and **Alejandra Alvarado** (aalvarado2@eiu.edu), Mathematics and Computer Science, 600 Lincoln Avenue, Charleston, IL 61920. *Arithmetic Progressions on Curves.*

The set $\{1,\ 25,\ 49\}$ is a 3-term collection of integers which forms an arithmetic progression; the common difference is 24. Hence the set $\{(1,1),\ (5,25),\ (7,49)\}$ is a 3-term collection of rational points on the parabola $y = x^2$ whose y-coordinates form an arithmetic progression. Similarly, the set $\{6,\ 12,\ 18\}$ is a 3-term collection of integers which also forms an arithmetic progression; the common difference is 6. Hence the set $\{(6,3),\ (12,39),\ (18,75)\}$ is a 3-term collection of rational points on the elliptic curve $y^2 = x^3 - 207$ whose x-coordinates form an arithmetic progression. Are there other examples such as these? What is the longest progression of rational points on either a quadratic or cubic curve such that either the x- or y-coordinates form an arithmetic progression? In this talk, we give a survey on what's known about arithmetic progressions on algebraic curves. We introduce elliptic curves as a means to show the non-existence of certain arithmetic progressions. We also introduce bielliptic curves in order to settle conjectures of Saraju P. Mohanty. (Received August 28, 2014)

1106-11-448 **Chris Jennings-Shaffer*** (cjenningsshaffer@ufl.edu). *Congruences for the Number of Smallest Parts in Partitions.*

One point of interest in counting the number of parts in partitions, and of related partition like objects, are the Ramanujan type congruences of the generating functions. We discuss two q-series techniques for proving such congruences. Both methods start by taking a generating function S(q) for the smallest parts function and introducing a new variable to get a function S(z,q) with S(1,q) = S(q). One technique is to find the dissection of the series S(z,q) when z is a fixed root of unity. The second is to find an identity expressing S(z,q) as a Hecke-type double sum in which it is convenient to set z to be root of unity. Both methods have their advantages and disadvantages. For examples we look at the number of smallest parts in overpartitions with various restrictions. (Received September 15, 2014)

1106-11-487 **Michael J Griffin*** (mjgrif3@emory.edu), Dept. of Math and CS, Emory University, 400 Dowman Dr., W401, Atlanta, GA 30322, and **Claudia Alfes**, **Ken Ono** and **Larry Rolen**. *Weierstrass mock modular forms and elliptic curves.*

Mock modular forms, which give the theoretical framework for Ramanujan's enigmatic mock theta functions, play many roles in mathematics. We study their role in the context of modular parameterizations of elliptic curves $E/\mathbb{Q}$. We show that mock modular forms which arise from Weierstrass ζ-functions encode the central L-values and L-derivatives which occur in the Birch and Swinnerton-Dyer Conjecture. By defining a theta lift using a kernel recently studied by Hövel, we obtain canonical weight 1/2 harmonic Maass forms whose Fourier coefficients encode the vanishing of these values for the quadratic twists of E. We employ results of Bruinier and the third author, which builds on seminal work of Gross, Kohnen, Shimura, Waldspurger, and Zagier. We also obtain p-adic formulas for the corresponding weight 2 newform using the action of the Hecke algebra on the Weierstrass mock modular form. (Received September 08, 2014)

1106-11-561 **Chieh-Yu Chang** and **Matthew A. Papanikolas*** (map@math.tamu.edu), Department of Mathematics, 3368 TAMU, Texas A&M University, College Station, TX 77843, and **Jing Yu**. *Eulerian multizeta values over function fields.*

A classical multiple zeta value (MZV) is said to be Eulerian if it is a rational multiple of a power of π. Examples of Eulerian MZV's abound and date back at least to Euler. In the setting of function fields over a finite field, Thakur defined multizeta values in direct analogy with classical MZV's, and Anderson and Thakur showed that they arise as periods of iterated extensions of the Carlitz motive. In this talk we will investigate a new criterion for determining when a function field MZV is Eulerian, in this case meaning that it is a rational multiple of a power of the Carlitz period. Furthermore we will discuss how this criterion can be used effectively to show whether or not a given MZV is Eulerian and present computational findings that confirm conjectures of Thakur and Lara Rodríguez. (Received September 02, 2014)

1106-11-586 **Anne M. Ho*** (ho@math.colostate.edu). *Counting Artin-Schreier Curves Over Finite Fields.* Preliminary report.

A number of authors have considered the weighted sum of various types of curves with a certain genus g over a finite field $k := \mathbb{F}_q$ of a specific characteristic. These include elliptic curves (Howe), hyperelliptic curves (Van der Geer, Van der Vlught), and Artin-Schreier curves (Cardona, Nart, Pujolàs, Sadornil). We denote this weighted sum as $\sum_{[C]} 1/|\mathrm{Aut}_k(C)|$, where the sum is over k-isomorphism classes of the curves and $\mathrm{Aut}_k(C)$ is the automorphism group of C over k. We extend the work of these authors by considering a related weighted sum for Artin-Schreier curves with a given genus g over fields of any characteristic p. We will discuss our results and methods of counting, which include looking at ramification divisors, finding associated rational models $y^p - y = u(x)$, and examining the actions of $\mathrm{PGL}_2(k)$ on the models. In addition, we will discuss the geometric connections to the moduli space of Artin-Schreier covers. (Received September 02, 2014)

1106-11-588 **Sungjin Kim*** (707107@gmail.com), 3767 Mentone Ave #306, Los Angeles, CA 90034. *Average of the First Invariant Factor of the Reductions of Abelian Varieties of CM Type.*

For a field of definition k of an abelian variety $\mathcal{A}$ and prime ideal $\mathfrak{p}$ of k which is of a good reduction for $\mathcal{A}$, the structure of $\mathcal{A}(\mathbb{F}_\mathfrak{p})$ as abelian group is:

$$\mathcal{A}(\mathbb{F}_\mathfrak{p}) \simeq \mathbb{Z}/d_1(\mathfrak{p})\mathbb{Z} \oplus \cdots \oplus \mathbb{Z}/d_g(\mathfrak{p})\mathbb{Z} \oplus \mathbb{Z}/e_1(\mathfrak{p})\mathbb{Z} \oplus \cdots \oplus \mathbb{Z}/e_g(\mathfrak{p})\mathbb{Z}, \tag{1}$$

where $d_i(\mathfrak{p})|d_{i+1}(\mathfrak{p})$, $d_g(\mathfrak{p})|e_1(\mathfrak{p})$, and $e_i(\mathfrak{p})|e_{i+1}(\mathfrak{p})$ for $1 \le i < g$.

We are interested in finding an asymptotic formula for the number of prime ideals $\mathfrak{p}$ with $N\mathfrak{p} < x$, $\mathcal{A}$ has a good reduction at $\mathfrak{p}$, $d_1(\mathfrak{p}) = 1$. We succeed in this under the assumption of the Generalized Riemann Hypothesis (GRH). Unconditionally, we achieve a short range asymptotic for abelian varieties of CM type, and the full cyclicity theorem for elliptic curves over a number field containing CM field. (Received September 02, 2014)

1106-11-612 **Alfred Geroldinger** and **David J. Grynkiewicz*** (diambri@hotmail.com), Department of Mathematical Sciences, University of Memphis, Memphis, TN 38152, and **Pingzhi Yuan**. *On Sets of Lengths in Krull Monoids.*

Let H be Krull Monoid with finite class group G such that every class contains a prime divisor. Given a product of k atoms $u_1 \cdot \ldots \cdot u_k$, we can ask what integers $t \ge 1$ are potential lengths of alternative factorizations: $u_1 \cdot \ldots \cdot u_k = v_1 \cdot \ldots \cdot v_t$ with the v_i also atoms. Let $\mathcal{V}_k(H)$ denote the union of all such t, ranging over all possible products of k atoms $u_1 \cdot \ldots \cdot u_k$. In other words, $\mathcal{V}_k(H)$ is the set of potential alternative factorization lengths available to any product of k atoms in H. It is known that $\mathcal{V}_k(H)$ is a finite interval, completely determined by its maximal value $\rho_k(H)$. We focus on some new results regarding the constant $\rho_k(H)$ achieved via methods from Combinatorial Number Theory. (Received September 03, 2014)

1106-11-641 **Steven J Miller*** (sjm1@williams.edu). *From Fibonacci Quilts to Benford's Law through Zeckendorf Decompositions.*

Zeckendorf's theorem states that every integer can be writen uniquely as a sum of non-adjacent Fibonacci numbers; we call this a legal decomposition. We report on some recent progress on generalizations and related questions. In particular, we discuss two very different situations where Benford's law of digit bias emerges (which states that the probability of observing a first digit of d is $\log_{10}(1 + 1/d)$). The first is in the distribution of leading digits of the summands in the Zeckendorf decompositions of integers; we concentrate on the Fibonacci case, but the proof extends to other difference equations. The second involves another sequence generated by a difference equation, which can be interpreted as the unique sequence arising from imposing a rule for a legal decomposition from the geometry of the Fibonacci spiral. In this situation we lose uniqueness of decomposition. We prove that approximately 92.6% of the time the greedy algorithm terminates in a legal decomposition here, and the average number of legal decompositions of numbers at most n follows Benford's law. This is joint work with many colleagues, especially A. Best, M. Catral, P. Dynes, X. Edelsbrunner, P. Ford, P. Harris, B. McDonald, D. Nelson, K. Tor, C. Turnage-Butterbaugh and M. Weinstein. (Received September 03, 2014)

1106-11-659 **Robin French*** (rfrench3@elon.edu) and **Chad Awtrey**. *A new algorithm for Galois groups of quintic polynomials.*

Finding solutions of polynomial equations is a central problem in mathematics. Of particular importance is the ability to solve a polynomial "by radicals"; i.e., using only the coefficients of the polynomial, the four basic arithmetic operations (addition, subtraction, multiplication, division), and roots (square roots, cube roots, etc.). For example, the existence of the quadratic formula shows that all quadratic polynomials are solvable by radicals. In addition, degree three polynomials and degree four polynomials are also solvable by radicals, which was shown in the 16th century. However, the same is not true for all degree five polynomials. Therefore, we are left with the following question: how do we determine which degree five polynomials are solvable by radicals? To answer this question, we study an important object that is associated to every polynomial. This object, named after 19th century mathematician Evariste Galois, is known as the polynomial's Galois group. The characteristics of the Galois group encode arithmetic information regarding its corresponding polynomial, including whether or not the polynomial is solvable by radicals. In this talk, we will discuss a new algorithm for determining the Galois group of a degree five polynomial. (Received September 04, 2014)

1106-11-702 **Andrew Niles*** (aniles@holycross.edu), Dept. of Mathematics & Computer Science, College of the Holy Cross, 1 College Street, Worcester, MA 01610. *Moduli of elliptic curves via twisted stable maps.*

In this talk, we compare two ways of compactifying certain arithmetic stacks of elliptic curves with level structure. On the one hand, we have the well-known Katz-Mazur regular models, whose cusps were given a moduli interpretation by Deligne and Rapoport in characteristics not dividing the level and by Conrad in arbitrary characteristic. On the other hand, a special case of the work of Abramovich, Olsson and Vistoli regarding twisted stable maps yields proper moduli stacks containing stacks of elliptic curves with level structure as locally closed substacks. We show that in this second case, the closure of the stack of elliptic curves with level structure admits a natural moduli interpretation. Furthermore, the resulting moduli stack is isomorphic to the Katz-Mazur regular model, and this isomorphism also has a moduli interpretation. (Received September 04, 2014)

1106-11-706 **Richard C. Burge***, rchrdbrg@gmail.com. *A Jacobi-Perron Variant and Hermite's Problem.* Preliminary report.

A new variant of the classical Jacobi-Perron algorithm will be introduced. Experimental data will be presented suggesting this single algorithm, whose domain is all the real numbers, finds a periodic representation for precisely those numbers which are cubic irrationalities. (Received September 04, 2014)

1106-11-723 **Ari Shnidman*** (shnidman@umich.edu). *Heights of generalized Heegner cycles.*

I will discuss a Gross-Zagier formula for even weight modular forms together with Hecke characters of smaller weight and applications to constructing non-trivial elements of certain Selmer groups. (Received September 05, 2014)

1106-11-727 **Thomas Hulse**, **Mehmet Kiral**, **Chan Ieong Kuan** and **Li-Mei Lim*** (llim@simons-rock.edu). *Counting Square Discriminants.*

Hee Oh and Nimish Shah prove that the number of integral binary quadratic forms whose coefficients are bounded by a quantity X, and with discriminant a fixed square integer d, is $cXlogX + O(X(logX)^{3/4})$. This result was obtained by the use of ergodic methods. Here we use the method of shifted convolution sums of Fourier coefficients of certain automorphic forms to obtain a sharpened result of a related asymptotic, obtaining a second main term and an error of $O(X^{1/2})$. (Received September 05, 2014)

1106-11-816 **Olivia Beckwith*** (olivia.dorothea.beckwith@emory.edu) and **Christine Bessenrodt** (bessen@math.uni-hannover.de). *Multiplicative properties of the number of k-regular partitions.*

In a previous paper of the second author with K. Ono, surprising multiplicative properties of the partition function were presented. Here, we deal with k-regular partitions. Extending the generating function for k-regular partitions multiplicatively to a function on k-regular partitions, we show that it takes its maximum at an explicitly described small set of partitions, and can thus easily be computed. The basis for this is an extension of a classical result of Lehmer, from which an inequality for the generating function for k-regular partitions is deduced which seems not to have been noticed before. (Received September 07, 2014)

1106-11-833 **Zev Klagsbrun** and **Robert J Lemke Oliver*** (rjlo@stanford.edu), Department of Mathematics, Building 380, Stanford University, Stanford, CA 94305. *The distribution of the Tamagawa ratio in the family of elliptic curves with a two-torsion point.*

In recent work, Bhargava and Shankar have shown that the average size of the 2-Selmer group of an elliptic curve over $\mathbb{Q}$ is exactly 3, and Bhargava and Ho have shown that the average size of the 2-Selmer group in the family of elliptic curves with a marked point is exactly 6. In contrast to these results, we show that the average size of the 2-Selmer group in the family of elliptic curves with a two-torsion point is unbounded. The existence of a two-torsion point implies the existence of rational isogeny, and a fundamental quantity attached to a pair of isogenous curves is the Tamagawa ratio, which measures the relative sizes of the Selmer groups associated to the isogeny and its dual. In the family of elliptic curves with a two-torsion point, we show that the Tamagawa ratio is essentially governed by a normal distribution with mean zero and growing variance, which implies the unboundedness of the average size of the 2-Selmer group. (Received September 07, 2014)

1106-11-839 **Luca Candelori*** (lcandelori@lsu.edu). *An algebro-geometric theory of vector-valued modular forms of half-integral weight attached to Weil representations.*

In this work we give a geometric theory of vector-valued modular forms attached to Weil representations of rank 1 lattices. More specifically, we construct vector bundles $\mathcal{V}_{m,k}$ over the moduli stack $\mathcal{M}_1$ of elliptic curves, whose sections over the complex numbers give weight $k+1/2$ vector-valued modular forms attached to rank 1 lattices with quadratic form $x \mapsto mx^2/2$, for $m \in 2\mathbb{Z}_{>0}$. The key idea is to construct vector bundles of Schrödinger representations and line bundles of half-forms over appropriate 'metaplectic stacks', which are μ_2-gerbes over $\mathcal{M}_1$, and then show that their tensor products $\mathcal{V}_{m,k}$ descend to $\mathcal{M}_1$. We then extend the bundles $\mathcal{V}_{m,k}$ to the cusp ∞ and give an algebraic notion of q-expansions of vector-valued modular forms. We define holomorphic vector-valued modular forms and cusp forms and compute algebraic dimension formulas for these spaces over any algebraically closed field of characteristic $\neq 2,3$, by using the Riemann-Roch theorem for DM stacks. Finally, by specializing the theory to the case $m=2$, we obtain an algebro-geometric theory of modular forms of half-integral weight, as defined in the complex-analytic case by Shimura. (Received September 07, 2014)

1106-11-840 **Kirsten Graham Wickelgren*** (kwickelgren3@math.gatech.edu), School of Mathematics, 686 Cherry Street, Atlanta, GA 30308. *Étale π_1 obstructions to rational points on Fermat curves.*

Jordan Ellenberg introduced obstructions to rational points coming from the lower central series of the étale fundamental group. This talk will describe joint work with Rachel Davis, Rachel Pries, and Vesna Stojanoska towards computing Ellenberg's 2-nilpotent obstruction for Fermat curves, using a description of the homology of Fermat curves due to Greg Anderson. (Received September 07, 2014)

1106-11-852 **Michael H. Mertens*** (mmertens@math.uni-koeln.de). *Holomorphic Projection and Mock Modular Forms.*

We give survey about a specific tool in the theory of harmonic Maass forms and mock modular forms, *holomorphic projection*. We describe how to use it to

a) construct examples of mock modular forms
b) prove Eichler-Selberg-type recurrences for Fourier coefficients of mock theta functions
c) establish a connection between mock modular forms and a certain kind of L-functions.

Parts of this talk are based on joint work with Ken Ono. (Received September 08, 2014)

1106-11-870 **Sharon M Frechette*** (sfrechet@holycross.edu), Department of Mathematics & Computer Science, College of the Holy Cross, 1 College Street, Worcester, MA 01543, and **Lance Robson** and **Julia Gordon**. *Orbital Integrals and Shalika Germs for $\mathfrak{sl}_n$ and $\mathfrak{sp}_{2n}$.*

Shalika germs were introduced as a tool for the study of orbital integrals, which arise in the trace formula and play a large role in harmonic analysis on p-adic groups. The Shalika germ expansion expresses regular semisimple orbital integrals as linear combinations of nilpotent ones, in a neighborhood of the origin. Shalika germs, by definition, are functions on the set of regular semisimple elements in a Lie algebra, and except for a few Lie algebras of small rank, their exact values elude computation. We prove that Shalika germs on the Lie algebra $\mathfrak{sl}_n$ and $\mathfrak{sp}_{2n}$ belong to a class of the so-called "motivic functions," defined by R. Cluckers and F. Loeser by means of a first-order language of logic (Denef-Pas language). This result has implications for the nature of bounds on the Shalika germs. The proof involves an explicit combinatorial matching, due to M. Nevins, between the parametrization of nilpotent orbits using partitions, and DeBacker's parametrization arising from the Bruhat-Tits building. This is joint work with Julia Gordon and Lance Robson. (Received September 08, 2014)

1106-11-886 **Z. Tripp*** (trippzac@gmail.com), 113 Tilton Hall, Tufts University, Medford, MA 02155. *Characterizing Primality in Numerical Monoids.* Preliminary report.

Numerical monoids, subsets of the natural numbers closed under addition, have numerous applications in various areas of mathematics. While they have been studied extensively, the ω-primality function, which says "how prime" an element is, is a relatively new factorization property. Previously, the ω function was characterized in numerical monoids generated by two elements, while in numerical monoids generated by three elements, examples showing some of the possible orderings of the omega values of the generators were illustrated. Additionally, it has recently been shown that the ω function is eventually quasi-linear in these monoids. While this should allow for easier computation of large values in numerical monoids, the lower bound given was often too large for reasonable computation. In my presentation, I plan to discuss the characterization of the ω function on the generators of numerical monoids generated by three elements, as well as a new lower bound on the eventual quasi-linearity of the ω function. The characterization of the ω function in this case reveals restrictions on the ω function, while the new lower bound allows for the ω function to be easily computed for large values in many numerical monoids. (Received September 08, 2014)

1106-11-894 **Antonio Lei*** (antonio.lei@mat.ulaval.ca). *Universal norm of crystalline classes.* Preliminary report.

Let T be a crystalline p-adic representation of G_F, where F is a number field where p is unramified. We may define a Selmer group of T using Bloch-Kato's crystalline classes. Given a family of crystalline classes over the cyclotomic extension of F that satisfy certain compatibility conditions, I will talk about how to interpolate these classes by power series using Perrin-Riou exponential map. (Received September 08, 2014)

1106-11-937 **Jennifer Balakrishnan*** (balakrishnan@maths.ox.ac.uk), **Mirela Çiperiani**, **Jaclyn Lang**, **Bahare Mirza** and **Rachel Newton**. *Shadow lines in the arithmetic of elliptic curves.*

Given a triple (E, p, d), where E is a rank 2 elliptic curve over $\mathbb{Q}$, d is the discriminant of a quadratic imaginary number field K that satisfies the Heegner hypothesis for E with rank $E(K) = 3$, and p is a good ordinary prime that splits in K, the *shadow line* is a 1-dimensional subspace of $E(K) \otimes \mathbb{Q}_p$ which originally appeared in the work of Mazur and Rubin. We describe the computation of shadow lines associated to such triples (E, p, d). To do so, we give an explicit construction of the anticyclotomic p-adic height pairing. (Received September 08, 2014)

1106-11-943 **Daniel J Kriz*** (dkriz@math.princeton.edu). *Congruences between Abel-Jacobi images of generalized Heegner cycles and special values of p-adic L-functions.*

We study special values of the Bertolini-Darmon-Prasanna anticyclotomic p-adic L-function attached to a newform f in situations where f is congruent to an Eisenstein series for a prime p split in an imaginary quadratic field. This yields congruences between images under p-adic Abel-Jacobi maps of certain cycles with rational coefficients on generalized Kuga-Sato varieties and expressions in terms of classical quantities such as Bernoulli numbers and circular units. We pay particular attention to the case where f is attached to a rational elliptic curve with reducible mod p representation, which gives congruences between formal logarithms of the Heegner points of imaginary quadratic field and expressions involving class numbers. (Received September 09, 2014)

1106-11-976 **Robert Harron*** (rharron@math.hawaii.edu), Department of Mathematics, University of Hawai'i at Mānoa, 2565 McCarthy Mall (Keller Hall 401A), Honolulu, HI 96822. *Iwasawa theory of symmetric powers of modular forms.*

Symmetric powers of modular forms have proved to be a fertile subject for exploring the arithmetic of Galois representations beyond GL((2). We will discuss some recent results in the Iwasawa theory of symmetric powers of modular forms. (Received September 09, 2014)

1106-11-1017 **Irene Bouw**, **Jenny Cooley**, **Kristin E. Lauter*** (klauter@microsoft.com), **Elisa Lorenzo Garcia**, **Michelle Manes**, **Rachel Newton** and **Ekin Ozman**. *Bad reduction of genus 3 curves with complex multiplication.*

Let C be a smooth, absolutely irreducible genus-3 curve over a number field M. Suppose that the Jacobian of C has complex multiplication by a sextic CM-field K. Suppose further that K contains no imaginary quadratic subfield. We give a bound on the primes $\mathfrak{p}$ of M such that the stable reduction of C at $\mathfrak{p}$ contains three irreducible components of genus 1. (Received September 09, 2014)

1106-11-1023 **Wolfgang A. Schmid*** (schmid@math.univ-paris13.fr). *When is the sum of two sets of lengths a set of lengths?*

Let H be a (commutative) atomic monoid, that is a commutative cancellative semi-group where each element can be written as a product of irreducible elements. For a non-invertible element $b \in H$ we say that n is a length of b if there exist irreducibles $a_1, \dots, a_n$ such that $b = a_1 \dots a_n$. We denote by $L(b)$ the set of all n such that n is a length of b; for an invertible element b we set $L(b) = \{0\}$.

The question to be discussed in this talk is under which conditions (on H) the set $L(b)+L(b') = \{n+n' \colon n \in L(b),\ n' \in L(b')\}$, for $b, b' \in H$, is guaranteed to be again a set of lengths, that is $L(b) + L(b') = L(c)$ for some $c \in H$. Note that $L(b) + L(b') \subset L(bb')$ but the inclusion can be strict.

In particular, we give a complete answer for the case of Krull monoids where each class contains a prime divisors.

This is joint work with A. Geroldinger. (Received September 09, 2014)

1106-11-1061 **Brandon Levin*** (bwlevin@math.uchicago.edu). *An HN-theory for Kisin modules.*

We begin by introducing Kisin varieties in the context of Galois deformation rings. We will then describe a generalization of Fargues' HN-theory for finite flat group schemes to the larger category of Kisin modules. This HN-theory gives rise to stratifications of Kisin varieties. We also discuss partial results towards a tensor product theorem in this context. This is joint work with Carl Wang Erickson. (Received September 10, 2014)

1106-11-1073 **Philip L Bretz** (philip.l.bretz-1@ou.edu) and **Connor C McBryde*** (mcbryde@ou.edu). *Optimal bounds of $\pi(n)$ using Zagier's method.*

Zagier showed using elementary methods, that $\pi(n)$ can be bounded by $\frac{2}{3}\frac{n}{\log(n)} < \pi(n) < 1.7\frac{n}{\log(n)}$. His proof, which used strong induction and properties of the binomial coefficients, yielded upper and lower bounds that vary as a function of n. We improved on Dr. Zagier's claim by showing that the optimal bounds that can be obtained using Zagier's method are $\log(2)\frac{n}{\log(n)} < \pi(n) < \log(4)\frac{n}{\log(n)}$. (Received September 10, 2014)

1106-11-1099 **Joshua Harrington** and **Lenny Jones*** (lkjone@ship.edu), Department of Mathematics, Shippensburg University, Shippensburg, PA 17257, and **Alicia Lamarche**. *The Average Order of an Element of the Symmetric Group.* Preliminary report.

Let μ_n denote the average order of an element of the symmetric group on n letters. In 1968, Erdős and Turán conjectured that

$$\log(\mu_n) = O\left(\sqrt{n/\log(n)}\right).$$

Schmutz proved this conjecture in 1989. His proof, which is nontrivial and relies on very technical results from partition theory, can be used to determine the smallest positive constant C such that

$$\mu_n \le n!^C \quad \text{for all } n \ge 1.$$

We determine C using a technique that requires only elementary methods. (Received September 10, 2014)

1106-11-1113 **Ashvin Anand Swaminathan*** (aaswaminathan@college.harvard.edu), 388 Eliot Mail Center, Harvard College, 101 Dunster Street, Cambridge, MA 02138. *On Arboreal Galois Representations of Rational Functions.*

The action of the absolute Galois group $\mathrm{Gal}(K^{\mathrm{sep}}/K)$ of a global field K on a tree $T(\phi, \alpha)$ of iterated preimages of $\alpha \in \mathbb{P}^1(K)$ under $\phi \in K(x)$ with $\deg(\phi) \ge 2$ induces a homomorphism $\rho : \mathrm{Gal}(K^{\mathrm{sep}}/K) \to \mathrm{Aut}(T(\phi, \alpha))$, called an arboreal Galois representation. We address questions of Jones and Manes about the size of $G(\phi, \alpha) := \mathrm{im}\rho$. We consider two cases: (1) ϕ is such that $\{a_n\}$ defined by $a_0 = \alpha$ and $a_n = \phi(a_{n-1})$ is periodic, and (2) ϕ commutes with a nontrivial Möbius transformation that fixes α.

In the first case, we resolve a question of Jones about the size of $G(\phi, \alpha)$, and taking $K = \mathbb{Q}$, we describe the Galois groups of iterates of $\phi \in \mathbb{Z}[x]$ when $\phi(x) = x^2+kx$ or $\phi(x) = x^2-(k+1)x+k$. Taking $\phi(x) = x^2+kx \in \mathbb{Z}[x]$, we employ a result of Jones regarding the size of the group $G(\psi, 0)$, where $\psi(x) = x^2 - kx + k$, to obtain a zero-density result for primes dividing terms of $\{a_n\}$. In the second case, we resolve a conjecture of Jones about the size of a certain subgroup $C(\phi, \alpha) \subset \mathrm{Aut}(T(\phi, \alpha))$ that contains $G(\phi, \alpha)$. (Received September 10, 2014)

1106-11-1207 **Lenny Jones** and **Alicia Lamarche*** (al5903@ship.edu), Department of Mathematics, Shippensburg University, Shippensburg, PA 17257. *Modular Solvability of Non-Solvable Diophantine Equations.* Preliminary report.

There are many examples of equations which have no integer solutions but do have solutions modulo n for every positive integer n. For example, there are classes of polynomials that possess this property. Additionally, in 2007 Mollin was able to provide conditions for Diophantine equations of the form $ax^2 + by^2 = \pm 1$ so that there are no solutions over the integers, yet there are solutions modulo n for every n. In this talk, we investigate equations which have similar properties. (Received September 11, 2014)

1106-11-1220 **Armin Straub*** (astraub@illinois.edu). *Congruences for Fishburn numbers modulo prime powers.*

The Fishburn numbers $\xi(n)$ are defined by the formal power series

$$\sum_{n\geq 0} \xi(n) q^n = \sum_{n\geq 0} \prod_{j=1}^{n} (1-(1-q)^j).$$

Recently, G. Andrews and J. Sellers discovered congruences of the form $\xi(pm+j) \equiv 0$ modulo p, valid for all $m \geq 0$. These congruences have then been complemented and generalized to the case of r-Fishburn numbers by F. Garvan. In this talk, we answer a question of Andrews and Sellers regarding an extension of these congruences to the case of prime powers. We show that, under a certain condition, all these congruences indeed extend to hold modulo prime powers. (Received September 11, 2014)

1106-11-1225 **Bryden Cais*** (cais@math.arizona.edu) and **Tong Liu**. *On the restriction of F-crystalline p-adic Galois representations.*

Let K be a finite extension of $\mathbf{Q}_p$, and let K_∞ be the extension of K obtained by adjoining a compatible system of p-power roots of a uniformizer of K. A theorem of Kisin asserts that the restriction of crystalline (p-adic) G_K-representations to G_{K_∞} is fully faithful. We generalize this theorem to include a large class of infinite, totally wildly ramified strictly APF extensions of K. (Received September 11, 2014)

1106-11-1283 **Byungchan Kim*** (bkim4@seoultech.ac.kr), 232 Gongreungro. nowongu, Seoul, 139-743, South Korea. *On the distributions of rank type functions.*

In this talk, I will briefly outline recent development of asymptotic distributions of partition rank like functions. (Received September 11, 2014)

1106-11-1367 **Jonathan Webster*** (jewebste@butler.edu), 4600 Sunset Ave, Indianapolis, IN 46205, and **Jon Sorenson**. *The Search for Small Pseudoprimes.* Preliminary report.

It was recently verified that 3825 12305 65464 13051 is the smallest pseudoprime to the first 11 prime bases. We show that the expected cost of searching for the smallest pseudoprime to the first k prime bases up to a bound B is on the order of $B^{2/3}$. We present progress on the computational search for the smallest pseudoprimes to first $k > 11$ prime bases. (Received September 12, 2014)

1106-11-1384 **Alexander Berkovich*** (alexb@ufl.edu). *On some implications of 1907 Hurwitz formula.*

I start by showing that a 1907 Hurwitz formula is a special case of the Siegel formula for ternary quadratic forms. I then employ the 1907 Hurwitz formula and a special case of the Jacobi triple product identity to prove certain conjectures of Kaplansky. In particular, I will show that $9x^2+16y^2+36z^2+16yz+4xz+8xy$ represents, exclusively, all positive integers not of the form

$4^a(8m+7)$

$4^a(8m+3), a=0,1,2$

$4^a(4m+2), a=0,1,2$

$4^a(8m+5), a=0,1$

$M^2, 4M^2$,

where a, m, M are non-negative integers and M is generated by 1 and primes congruent to $1 \pmod 4$. (Received September 12, 2014)

1106-11-1464 **Frank Garvan*** (fgarvan@ufl.edu), Department of Mathematics, University of Florida, PO BOX 118105, Gainesville, FL 32611-8105. *Congruences and relations for the Fishburn numbers.*

The Fishburn numbers occur as coefficients of Konstevich's strange quantum modular form. We show how we discovered and proved new congruences and relations for the Fishburn numbers and their relatives. (Received September 13, 2014)

1106-11-1541 **Wen-Ching Winnie Li*** (wli@math.psu.edu), Department of Mathematics, Penn State University, University Park, PA 16802. *Modular Forms for Congruence and Noncongruence Subgroups.*

The arithmetic of modular forms for congruence subgroups of SL(2, Z) has been a central theme in number theory for over one century. It has close connections with many branches of mathematics. Wiles's proof of Fermat's Last Theorem has brought the field to a new climax. The arithmetic of modular forms for noncongruence subgroups, on the other hand, has not attracted much attention in the past. However, the research in this area has been reinvigorated in the past decade.

This talk is an overview of the progress on modular forms for both congruence and noncongruence subgroups as well as the connections between these two kinds of forms. (Received September 14, 2014)

1106-11-1608 **Susie Kimport*** (susie.kimport@yale.edu). *Quantum modular forms from mock Jacobi forms.*

Quantum modular forms, introduced by Zagier in 2010, are functions that exhibit almost modular behavior on a subset of a rational numbers. Since their introduction, a handful of examples of these new objects have been generated. In this talk, I will present an infinite family of quantum modular forms of arbitrary half-integral weight. These forms arise from a universal mock theta function in a systematic way. Further, the method of construction extends results related to Jacobi forms into this quantum setting. (Received September 14, 2014)

1106-11-1624 **Thomas Garrity*** (tgarrity@williams.edu), Department of Mathematics and Statistics, Williams, Williamstown, MA 01267, and **Ilya Amburg** (ida1@williams.edu), Department of Physics, Williams, Williamstown, MA 01267. *A new family of multidimensional continued fractions: translated triangle maps.* Preliminary report.

Overall, this talk can be viewed as an introduction for methods for constructing multidimensional continued fraction algorithms. We will generalize a type of multidimensional continued fraction (the triangle map) to a new family of multidimensional continued fractions, which we call *translated triangle maps.* We will see, in a sharp, well-defined way, that the original triangle map is to translated triangle maps what the standard continued fraction

$$a_0 + \cfrac{1}{a_1 + \frac{1}{a_2 + \frac{1}{a_3 + \frac{1}{\ddots}}}}$$

is to the more general continued fraction

$$a_0 + \cfrac{b_1}{a_1 + \frac{b_2}{a_2 + \frac{b_3}{a_3 + \frac{b_4}{\ddots}}}}.$$

(Received September 14, 2014)

1106-11-1657 **Silas Johnson*** (sjohnson@math.wisc.edu). *Weighted Discriminants and Mass Formulas for Number Fields.* Preliminary report.

Kedlaya and Wood have explored alternate invariants for number fields, with the idea of replacing the discriminant in standard field-counting questions with one of these alternate invariants. We further explore the space of "reason- able" invariants, expanding on Kedlaya and Wood's definition. We also discuss a theorem on mass formulas for these invariants. (Received September 14, 2014)

1106-11-1679 **Karl Dilcher*** (dilcher@mathstat.dal.ca), Department of Mathematics & Statistics, Dalhousie University, Halifax, NS B3H 4R2, Canada, and **Larry Ericksen**. *Generalized Stern polynomials, hyperbinary expansions, and continued fractions.* Preliminary report.

We define a generalization of the Stern polynomials that were previously introduced by Dilcher and Stolarsky. These generalized polynomials characterize all hyperbinary expansions of a given positive integer. We then define two interrelated subsequences which can be seen as extensions or analogues of the Fibonacci numbers, and as limiting cases we obtain two classes of analytic functions. As an application we obtain evaluations of certain finite and infinite continued fractions whose partial quotients are doubly exponential, thus extending previous work related to Stern polynomials. (Received September 14, 2014)

1106-11-1735 **Olav K Richter** and **Jayantha N Senadheera*** (jayantha.senadheera@gmail.com), Department of Mathematics & Computer Science, Faculty of Natural Sciences, The Open University of Sri Lanka, Nawala 10250, Sri-Lanka. *Hermitian Jacobi Forms and Congruences.*

In this talk, I will report on recent joint work with Olav Richter on Hermitian Jacobi forms. We introduce a new space of Hermitian Jacobi forms, and we present a structure theorem for that space. Moreover, we characterize U(p) congruences for Hermitian Jacobi forms, and we illustrate our results with several examples. (Received September 15, 2014)

1106-11-1744 **Nathan Kaplan*** (nathan.kaplan@yale.edu), Yale University, Department of Mathematics, 10 Hillhouse Avenue, New Haven, CT 06511. *Higher Weight Enumerators and Rational Points on Intersections of Plane Curves.*

Let C_1 and C_2 be curves of degrees d and e, respectively, in the projective plane over the finite field $\mathbb{F}_q$. If these curves do not share a common component then Bezout's theorem implies that they intersect in at most $d \cdot e$ points. For any $k \in \{0, 1, \ldots, d \cdot e\}$, what is the probability that C_1 and C_2 intersect in exactly k $\mathbb{F}_q$-rational points?

We will discuss an approach to this question using a version of the MacWilliams theorem for higher weight enumerators of linear codes. We will focus on the case of intersections of cubic curves. (Received September 15, 2014)

1106-11-1748 **Brandt Kronholm*** (kronholm@risc.jku.at), Research Institute for Symbolic Computation, Johannes Kepler University, Altenberger Straße 69, A-4040 Linz, Austria, and **Felix Breuer** and **Dennis Eichhorn**. *A Supercrank for $P(n, 3)$ modulo Primes of the form $6j - 1$.*

In 1944, Dyson called for *direct* proofs of Ramanujan's congruences for $p(n)$ that give concrete demonstrations of how the associated partitions can be systematically divided into equinumerous classes. He conjectured that a very simple statistic on partitions, called the "rank" of a partition, performs this division when considered modulo 5 and 7. In the same paper, Dyson hypothesized the existence of a different statistic, called the "crank," that would witness Ramanujan's congruence modulo 11 in the same way.

Recent results show that Dyson's ideas can be applied to partitions of n into exactly d parts, denoted by $P(n, d)$. Moreover, some of these new cranks for $P(n, d)$ have a very surprising quality that is not shared with those for $p(n)$; there are cranks for $P(n, d)$ that witness *each and every* instance of divisibility modulo a given prime. We call these cranks *supercranks.*

In this talk, we make use of Ehrhart Geometry and other techniques to prove the following result:

Theorem (Breuer, Eichhorn, Kronholm)**.** *Largest part minus smallest part is a supercrank for $P(n, 3) \pmod{m}$ where m is any prime of the form $6j - 1$.* (Received September 15, 2014)

1106-11-1763 **Eva G. Goedhart*** (egoedhart@brynmawr.edu) and **Helen G. Grundman** (grundman@brynmawr.edu). *Diophantine Equations of the Form $X^{2N} + 2^{2\alpha}5^{2\beta}p^{2\gamma} = Z^5$.*

After a brief introduction to the modular approach of solving Diophantine equations and some key results derived by Bennett and Skinner using this method, I will discuss our recent proof that no equation of the form $X^{2N} + 2^{2\alpha}5^{2\beta}p^{2\gamma} = Z^5$, with p an odd prime and $\alpha > 0$, has integral solutions with $N > 1$ and $\gcd(X, Z) = 1$. (Received September 15, 2014)

1106-11-1767 **Eva G. Goedhart** (egoedhart@brynmawr.edu) and **Helen G. Grundman*** (grundman@brynmawr.edu). *On Solving the Equation $(a^2x^k - 1)(b^2y^k - 1) = (abz^k - 1)^2$.*

I will discuss our proof that the equation $(a^2x^k - 1)(b^2y^k - 1) = (abz^k - 1)^2$ has no positive integer solutions with $k \geq 7$ and $a^2x^k \neq b^2y^k$, extending the results of Bennett and of Zhang. Of key interest will be the use of Diophantine approximation and of computer calculations done by my coauthor as part of her dissertation research. (Received September 15, 2014)

1106-11-1783 **Katherine E Stange*** (kstange@math.colorado.edu), Department of Mathematics, Campus Box 395, University of Colorado Boulder, Boulder, CO 80309. *Visualising the arithmetic of quadratic imaginary fields.* Preliminary report.

We study the orbit of $\mathbb{R}$ under the Bianchi group $\mathrm{PSL}_2(\mathcal{O}_K)$, where K is an imaginary quadratic field. The orbit, called a Schmidt arrangement $\mathcal{S}_K$, is a geometric realisation, as an intricate circle packing, of the arithmetic of K. This paper presents several examples of this phenomenon. First, we show that the curvatures of the circles are integer multiples of $\sqrt{-\Delta}$ and describe the curvatures of tangent circles in terms of the norm form of $\mathcal{O}_K$. Second, we show that the circles themselves are in bijection with certain ideal classes in orders of $\mathcal{O}_K$, the conductor being a certain multiple of the curvature. This allows us to count circles with class numbers. Third, we show that the arrangement of circles is connected if and only if $\mathcal{O}_K$ is Euclidean if and only if the tangency graph contains loops. These results are meant as foundational for a study of a new class of thin groups generalising Apollonian groups. (Received September 15, 2014)

1106-11-1797 **T. Alden Gassert*** (thomas.gassert@colorado.edu), Department of Mathematics, Campus Box 395, Boulder, CO 80309. *Discriminants of simplest 3^n-tic extensions.*

Let $\ell > 2$ be a positive integer, ζ_ℓ a primitive ℓ-th root of unity, and K a number field containing $\zeta_\ell + \zeta_\ell^{-1}$ but not ζ_ℓ. In a recent paper, Chonoles et. al. study iterated towers of number fields over K generated by the generalized Rikuna polynomial, $r_n(x, t; \ell) \in K(t)[x]$. They note that when $K = \mathbb{Q}$, $t \in \{0, 1\}$, and $\ell = 3$, the only ramified prime in the resulting tower is 3, and they ask under what conditions is the number of ramified primes small. In this talk, we apply a theorem of Guàrdia, Montes, and Nart to derive a formula for the discriminant of $\mathbb{Q}(\theta)$ where θ is a root of $r_n(x, t; 3)$, answering the question of Chonoles et. al. in the case $K = \mathbb{Q}$, $\ell = 3$, and $t \in \mathbb{Z}$. (Received September 15, 2014)

1106-11-1801 **Ellen Eischen*** (eeischen@email.unc.edu). *p-adic q-expansions and families of automorphic forms.*

One approach to p-adically interpolating special values of certain L-functions relies on constructing p-adic families of automorphic forms. I will explain how to produce such p-adic families for certain unitary groups. In particular, this talk will focus on the q-expansions (and certain analogues of q-expansions) of these forms. I will also mention some applications to number theory and beyond. (Received September 15, 2014)

1106-11-1861 **Francesc Castella*** (castella@math.ucla.edu), Department of Mathematics, 520 Portola Plaza, Los Angeles, CA 90095-1555, and **Ming-Lun Hsieh**. *Generalised Heegner cycles and p-adic L-functions.*

We will describe an explicit reciprocity law for generalised Heegner cycles in terms of certain Rankin-Selberg L-values, and explain the applications of this formula to new "rank 0" cases of the Bloch-Kato conjecture. (Received September 15, 2014)

1106-11-1877 **William Y Chen*** (chen_w@math.psu.edu), 445 Waupelani Dr., Apt D17, State College, PA 16801. *Moduli Interpretations for Noncongruence Modular Curves.*

Let Γ be a subgroup of $\mathrm{SL}_2(\mathbb{Z})$, and let $\mathcal{H}$ be the upper half plane. If Γ is a congruence subgroup, then it's well known that the quotient $\Gamma \setminus \mathcal{H}$ is a coarse moduli space for isomorphism classes of elliptic curves equipped with some level structure. We will generalize the standard level structures and show that for most noncongruence subgroups Γ, the quotient $\Gamma \setminus \mathcal{H}$ has a natural interpretation as the coarse moduli space classifying isomorphism classes of elliptic curves together with a generalized level structure. In this generalization the standard level structures associated to congruence subgroups should be considered "abelian", while those corresponding to noncongruence subgroups should be considered "nonabelian". We will also discuss applications to the arithmetic of noncongruence modular forms. (Received September 15, 2014)

1106-11-1887 **Michelle R. DeDeo*** (mdedeo@unf.edu), 1 UNF Dr., Dept. of Mathematics and Statistics, Jacksonville, FL 32224. *Thoughts on the Energy of Ramanujan graphs.* Preliminary report.

Graph energy is a mathematically interesting topic. Although this topic was introduced in the mathematical literature in the 1970s, and has a still older chemical origin, deeper connections to chemistry and graph theory were not developed until recently. Since 2006, when the first extension was put forward, an unexpectedly large number of graph energies appeared. While this work is theoretical, these concepts have made great contributions to fields such as computer networks, chemistry and spectral graph theory.

In particular, whenever a new "energy" was introduced, one of the first tasks was to find bounds for the energy. Generalized bounds have been reported for practically all of the types of graph energies, but these bounds are non-specific. What authors have yet to accomplish is to determine strict graph energy bounds for several important classes of graphs such as Ramanujan graphs. The foundation of this talk is to share ideas regarding the energy of Ramanujan graphs end explore their meaning. (Received September 15, 2014)

1106-11-1904 **Arunabha Biswas*** (arunabha.biswas@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Broadway and Boston, Lubbock, TX 79409. *Asymptotic nature of higher Mahler Measure.*

We consider the k-higher Mahler measure $m_k(P)$ of a Laurent polynomial P as the integral of $log^k|P|$ over the complex unit circle. In this talk we present some new asymptotic results regarding $m_k(P)$ especially an explicit formula for the value of $|m_k(P)|/k!$ as $k \to \infty$. (Received September 15, 2014)

1106-11-1936 **Philipp Habegger** and **Su-ion Ih*** (ih@math.colorado.edu). *Distribution of integral division points on the algebraic torus.*

We will talk about the distribution of heights of integral division points on the algebraic torus. (Joint work with P. Habegger) (Received September 15, 2014)

1106-11-1985 **Jinghao Li*** (jinghao@math.binghamton.edu) and **Adrian Vasiu**. *Purity Results on F-crystals.*

We will present a survey of purity results for stratifications in positive characteristic associated to F-crystals, including some recent new purity results. (Received September 15, 2014)

1106-11-2050 **Carl Alan Libis*** (clibis@utm.edu), UT Martin, Department of Mathematics and Statistics, 424 Humanities Building, Martin, TN 38238. *Generalized Pascal's Triangle.* Preliminary report.

The typical way of generalizing is to look at a trinomial expansion instead of a binomial expansion. We will generalize by changing one of the two outside diagonals of 1's to a different positive integer constant. We will summarize some past results as well as present some new result. (Received September 15, 2014)

1106-11-2054 **Timothy James All*** (all1@rose-hulman.edu), 5500 Wabash Ave, Terre Haute, IN 47803, and **Bradley Arthur Waller**. *On a construction of $C^1(\mathbb{Z}_p)$ functionals from $\mathbb{Z}_p$-extensions of algebraic number fields.*

Let k be any number field and k_∞/k any $\mathbb{Z}_p$-extension. We construct a natural $\Lambda = \mathbb{Z}_p[[T-1]]$-morphism from $\varprojlim k_n^\times \otimes_\mathbb{Z} \mathbb{Z}_p$ into a special subset of $C^1(\mathbb{Z}_p)^*$, the collection of linear functionals on the set of continuously differentiable functions from $\mathbb{Z}_p \to \mathbb{C}_p$. We apply the results to the problem of interpolating Gauss sums attached to Dirichlet characters and the explicit annihilation of real ideal classes. (Received September 15, 2014)

1106-11-2109 **Adam Topaz*** (atopaz@math.berkeley.edu), Dept. of Math., Univ. of California, Berkeley, 970 Evans Hall #3840, Berkeley, CA 94720-3840. *Model theory and Mod-ℓ Galois theory.*

This talk describes some recent results in Galois theory of function fields which use model-theoretic tools. More precisely, we use elements of geometric stability theory to develop a "global-theory" for the mod-ℓ anabelian geometry of higher-dimensional function fields. (Received September 15, 2014)

1106-11-2134 **Scott Zinzer*** (szinzer@asu.edu), 901 S Palm Walk, Tempe, AZ 85287. *p-adic measures on $\mathbb{Z}_p$ and $\mathbb{Z}_p^2$.* Preliminary report.

Let $\mathcal{O}$ be the ring of integers of a complete extension of $\mathbb{Q}_p$. We describe a procedure for converting certain collections of $\mathcal{O}$-valued measures on $\mathbb{Z}_p$ into $\mathcal{O}$-valued measures on $\mathbb{Z}_p^2$. We then derive some properties of measures constructed in this way and study the Γ-transform of these measures. (Received September 15, 2014)

1106-11-2148 **Archit Kulkarni** (auk@andrew.cmu.edu) and **David Moon*** (dm7@williams.edu). *Sets Characterized by Sums and Differences in Dilating Polytopes.*

In 2007, Hegarty showed that for any prescribed $s, d \in \mathbb{N}_0$, the proportion $\rho_n^{s,d}$ of subsets of $\{0,\ldots,n\}$ that are missing exactly s sums in $\{0,\ldots,2n\}$ and exactly $2d$ differences in $\{-n,\ldots,n\}$ also remains positive in the limit. We consider the following question: are such sets, characterized by their sums and differences, similarly ubiquitous in higher dimensional spaces? Let P be a polytope in $\mathbb{R}^D$ with vertices in $\mathbb{Z}^D$, and let $\rho_n^{s,d}$ now denote the proportion of subsets of $L(nP)$ that are missing exactly s sums in $L(nP)+L(nP)$ and exactly $2d$ differences in $L(nP)-L(nP)$. It turns out the geometry of P has a significant effect on the limiting behavior of $\rho_n^{s,d}$. We define a geometric feature of polytopes called local point symmetry, and show that $\rho_n^{s,d}$ is bounded below by a positive constant as $n \to \infty$ if and only if P is locally point symmetric. We also show that the proportion of subsets in $L(nP)$ missing exactly s sums and at least $2d$ differences remains positive in the limit, independent of the geometry of P. A corollary of these results is that if P is point symmetric, the proportion of sum-dominant subsets of $L(nP)$ also remains positive in the limit. (Received September 15, 2014)

1106-11-2158 **Dan King*** (kingd6@nku.edu), 673 Neal Howell Road, Bowling Green, KY 42104, and **Tom Richmond** (tom.richmond@wku.edu). *Patterns in Pythagorean Triples.* Preliminary report.

Euclid's formula is a fundamental formula for generating Pythagorean triples (PTs) given an arbitrary pair of positive integers m and n. The PT is primitive if and only if m and n are relatively prime. Consider the PTs as points in 3-space that lie on the cone $x^2 + y^2 = z^2$. These points can be thought of as vertices of polygons, particularly right triangles, on the cone. Pursuit of right triangles in 3-space with both PT vertices and integer edges has led to interesting results such as restrictions on certain integer distances. This presentation will examine the properties of integer distances between PT points in 3-space. (Received September 15, 2014)

1106-11-2159 **James D Martin*** (jamesmartin3@my.unt.edu). *Rankin-Cohen brackets for Hermitian Jacobi forms and for Hermitian modular forms.* Preliminary report.

In this talk, I will report on joint work with Jayantha Senadheera. I will discuss the actions of differential operators on Hermitian Jacobi forms and also on Hermitian modular forms of degree 2. In particular, I will present the constructions of Rankin-Cohen brackets for Hermitian Jacobi forms and for Hermitian modular forms of degree 2. (Received September 15, 2014)

1106-11-2279 **Alan Koch*** (akoch@agnesscott.edu), Box 1092, Agnes Scott College, 141 E. College Ave., Decatur, GA 30033. *Generalized integral Hopf-Galois module structure in characteristic p.*

Let L be a finite, purely inseparable, totally ramified extension of a discrete valuation field K of characteristic p, $[L:K]=p^n>p$. Let $\mathfrak{O}_L$ be the valuation ring of L, and let $\mathfrak{P}_L\subset\mathfrak{O}_L$ be its maximal ideal. There are numerous commutative, cocommutative K-Hopf algebras H which act on L in such a way as to make L/K a Hopf-Galois extension. We will construct a collection of such Hopf algebras, and for each we will investigate the structure of the fractional ideals of $\mathfrak{O}_L$ as modules over certain $\mathfrak{O}_L$-orders in the Hopf algebra. Explicitly, for each H in our collection, for $m\in\mathbb{Z}$ we define the associated order of $\mathfrak{P}_L^m$ in H to be $\mathfrak{A}_H(m)=\{h\in H: h\mathfrak{P}_L^m\subseteq\mathfrak{P}_L^m\}$; we will give a numerical criterion which will determine whether $\mathfrak{P}_L^m$ is a free $\mathfrak{A}_H(m)$-module. In particular, one can always choose an action of H on L such that $\mathfrak{O}_L$ is a free $\mathfrak{A}_H(0)$-module. (Received September 16, 2014)

1106-11-2291 **Levent Alpoge***, Harvard University, Cambridge, MA. *The average elliptic curve has few integral points.*

Counting the number of integer solutions to $y^2=x^3+Ax+B$ is an old, old problem — Fermat discussed the cases of $A=0$, $B=-2,-4$ when first presenting his method of descent, for instance. Siegel proved that such an equation can only have finitely many integral solutions given A and B (so long the equation actually gives an elliptic curve). How many should there be if we vary A and B? On average, the answer should be zero. I will show it is bounded and give an explicit upper bound. The methods will combine the recent results of Bhargava-Shankar on averaging Selmer groups, the Kabatiansky-Levenshtein bound from the theory of sphere packing, Roth's theorem in Diophantine approximation, and the observation that integral points tend to repel in the Mordell-Weil lattice (much like rational points on higher genus curves repel according to Mumford's gap principle). If time permits I will also mention similar results for thinner families: $y^2=x^3+B$, $y^2=x^3+Ax$, and the congruent number curves $y^2=x^3-D^2x$. (Received September 16, 2014)

1106-11-2300 **Caroline L. Turnage-Butterbaugh** (cturnagebutterbaugh@gmail.com), Mathematics Dept. 2750, PO Box 6050, North Dakota State University, Fargo, ND 58102. *Large gaps between zeros of the Dedekind zeta-function of a quadratic number field.* Preliminary report.

Let K be a quadratic number field with discriminant d. The Dedekind zeta-function attached to K can be expressed by $\zeta_K(s)=\zeta(s)L(s,\chi_d)$ for $s\neq 1$, where $\zeta(s)$ is the Riemann zeta-function, the character χ_d is the Kronecker symbol associated to d, and $L(s,\chi_d)$ is the corresponding Dirichlet L-function. Using amplifiers and assuming the generalized Riemann hypothesis for $\zeta_K(s)$, we improve the results on large gaps between the nontrivial zeros of $\zeta_K(s)$. This is joint work with Hung Bui and Winston Heap. (Received September 16, 2014)

1106-11-2325 **John F. R. Duncan** and **Sander Mack-Crane*** (mack-crane@case.edu). *The Moonshine Module for Conway's Group.*

Monstrous moonshine is a phenomenon that deeply links groups of isometries of the hyperbolic plane to the representation theory of the monster group, the largest sporadic simple group. Each element of the monster group is associated to a function on the hyperbolic plane which generates the field of functions invariant under a certain group of isometries (such a function is called a principal modulus for the group).

Frenkel–Lepowsky–Meurman illuminated this relationship by constructing a graded module for the monster group, whose graded trace by a monster element produces a principal modulus for the isometry group associated to that element of the monster.

Conway and Norton's monstrous moonshine paper also describes a moonshine phenomenon for Conway's group, the automorphism group of the Leech lattice. We construct the analog of the monster module for Conway's group, a graded module whose graded trace by a Conway element produces the principal modulus associated to that element by moonshine. This constitutes an important step toward a conceptual explanation for Conway moonshine. Our Conway module also finds application in physics, where we use it to compute twined elliptic genera of K3 sigma models. (Received September 16, 2014)

1106-11-2349 **Sandie Han**, **Ariane Masuda**, **Satyanand Singh** and **Johann Thiel***, 300 Jay St., Brooklyn, NY 11201. *The (u, v)-Calkin-Wilf Tree.* Preliminary report.

The Calkin-Wilf tree is an infinite binary tree whose vertices enumerate $\mathbb{Q}^+$ via a simple generation rule. This talk will focus on a generalization of the Calkin-Wilf tree involving two parameters, u and v, referred to as the (u, v)-Calkin-Wilf tree. We will show that several properties of the (u, v)-Calkin-Wilf tree can be understood through the use of continued fractions. Furthermore, we discuss extensions of several known symmetry results of the original Calkin-Wilf tree to this new setting. (Received September 16, 2014)

1106-11-2392 **Christelle Vincent*** (cvincent@stanford.edu), Stanford, CA 94305. *Weierstrass points on Drinfeld modular curves.*

We consider the so-called Drinfeld setting, a function field analogue of some aspects of the theory of modular forms, modular curves and elliptic curves. We are interested in studying a finite set of points of geometric interest, the Weierstrass points, of the curve $X_0(\mathfrak{p})$ for $\mathfrak{p}$ a prime ideal. We show that each supersingular j-invariant, except possibly the elliptic j-invariant $j = 0$, is the reduction modulo $\mathfrak{p}$ of the j-invariant of a Weierstrass point of the modular curve $X_0(\mathfrak{p})$. (Received September 16, 2014)

1106-11-2418 **Daniel Barrera**, **Mladen Dimitrov** and **Andrei Jorza*** (ajorza@nd.edu). *Derivatives of p-adic L-functions of Hilbert modular forms.*

P-adic L-functions are analogues of classical complex L-functions where the variable is a p-adic number instead of a complex one. Just like the Birch and Swinnerton-Dyer conjectures (and their generalizations) study the first Taylor coefficient of complex L-functions of Galois representations, so-called exceptional zero conjectures relate the first Taylor coefficients of p-adic L-functions to arithmetic information. This relationship encodes congruences between Hilbert modular forms and has wide-ranging applications. I will present recent results in the case of Hilbert modular forms. (Received September 16, 2014)

1106-11-2427 **Sandie Han**, **Ariane Masuda*** (amasuda@citytech.cuny.edu), **Satyanand Singh** and **Johann Thiel**, Department of Mathematics, New York City College of Technology, CUNY, 300 Jay Street, Brooklyn, NY 11201. *The Calkin-Wilf Tree for Linear Fractional Transformations.* Preliminary report.

The Calkin-Wilf tree is an infinite binary tree whose vertex set consists of all positive rational numbers. Recently, Nathanson introduced the linear fractional transformation analogue of the Calkin-Wilf tree. He showed that the set of positive linear fractional transformations can be partitioned into an infinite forest of infinite binary trees defined by the Calkin-Wilf tree generation rule. We will discuss some properties of this forest, including some applications of continued fractions. (Received September 16, 2014)

1106-11-2441 **Kevin M Mugo*** (kevin.mugo@gmail.com), W.Lafayette, IN 47906. *Mod 4 Galois Representations From Elliptic Curves and a Certain Brauer-Type Embedding Problem.*

Let $\overline{\rho}_{E,4}$ be a surjective Galois representation, induced by the action of G_K on the 4-torsion points of an elliptic curve E, with invariant j_0. We show that the unique S_4 field extension contained in $K(E[4])$ is the splitting field of the principal quartic $q(r) = r^4 + \dfrac{32}{j_0} + \dfrac{4}{j_0}$. We show that L/K is a principal, quartic extension precisely when a certain Brauer-Severi variety has a K-rational point. When L/K is principal, and M/K is its normal closure, we show that the solvability of the embedding problem $2S_4^+ \longrightarrow \mathrm{Gal}(M/K)$ is completely determined by the discriminant $d_{L/K}$. Moreover, we will show that if L/K is principal and the Hilbert symbol $(-2, -d_{L/K})$ is trivial, then the embedding problem $2S_4^+ \longrightarrow \mathrm{Gal}(M/K)$ is solvable. (Received September 16, 2014)

1106-11-2457 **K. McMurdy*** (kmcmurdy@ramapo.edu), kmcmurdy@ramapo.edu, and **N. Jones** and **J. Brau**. *Elliptic Curves with Non-abelian Entanglement Fields.* Preliminary report.

For a fixed elliptic curve, E, over the rational numbers, define an entanglement field for E to be the intersection between $\mathbb{Q}(E[m_1])$ and $\mathbb{Q}(E[m_2])$, where m_1 and m_2 are relatively prime. In this talk, we will discuss our ongoing efforts to classify, using explicit methods, entanglement fields which are non-abelian over the rational numbers. These results are related to statistical aspects of the arithmetic of elliptic curves. (Received September 16, 2014)

1106-11-2481 **Jeremy Allen Jacobson*** (jeremy.a.jacobson@emory.edu), 400 Dowman Dr, Atlanta, GA 30322, Mathematics and Science Center, Suite E427, Atlanta, GA 30329. *On the signature of a quadratic form.*

The signature of a quadratic form plays an important role in the study of quadratic forms in a Witt group. For any algebraic variety X over the real numbers $\mathbb{R}$, it allows one to relate quadratic forms over X to the singular cohomology of the real points $X(\mathbb{R})$. This has applications to bounding the order of torsion in the Witt group of quadratic forms over X. (Received September 16, 2014)

1106-11-2494 **Tim Huber*** (hubertj@utpa.edu). *Elliptic construction of modular generators.*
For prime levels p, a correspondence is presented between classes of elliptic functions and theta quotients generating graded algebras of modular forms of level p. Arithmetic consequences result from the common forms taken by certain combinatorial generating functions in terms of the modular parameters. (Received September 16, 2014)

1106-11-2517 **Bir B Kafle*** (bkafle@pnc.edu), 1401 S. US 421, SWRZ 310, Westville, IN 46391, and **Robert V Perlis**. *Local Conjugation in Groups and Applications to Number Fields.* Preliminary report.
Let G be a finite group. Two subgroups H, H' of G are said to be Gassmann equivalent if each conjugacy class of G intersects H and H' in the same number of elements. In 1192, Sheng Chen proved that H, H' are Gassmann equivalent if and only if H, H' are locally conjugate. Many applications of local conjugacy have been discovered. In this talk, I will discuss the local conjugacy in symmetric groups, a new reformulation of Gassmann equivalence and its application to number fields. (Received September 16, 2014)

1106-11-2572 **Mirela Ciperiani*** (mirela@math.utexas.edu). *Local points of supersingular elliptic curves on $\mathbb{Z}_p$-extensions.*
By work of Kobayashi and Iovita-Pollack we know that local points of supersingular elliptic curves on ramified $\mathbb{Z}_p$-extensions of $\mathbb{Q}_p$ split into two strands of even and odd points. We will discuss a generalization of this result to $\mathbb{Z}_p$-extensions that are localizations of anticyclotomic $\mathbb{Z}_p$-extensions over which the elliptic curve has non-trivial CM points. (Received September 16, 2014)

1106-11-2748 **Cormac O'Sullivan** and **Karen Taylor*** (karen.taylor@bcc.cuny.edu). *Hyperbolic Fourier coefficients of Poincaré series.*
Hans Petersson (1941) gave a uniform treatment of parabolic, elliptic and hyperbolic Poincaré series as spanning sets for holomorphic cusp forms. In an earlier paper, Petersson, gave, the now classical, expansion of the (parabolic) Fourier coefficients of (parabolic) Poincaré series in terms of Bessel functions and Kloosterman sums. In this paper we give the hyperbolic Fourier coefficients of holomorphic parabolic and hyperbolic Poincaré series in terms of hypergeometric series and generalized Kloosterman sums. (Received September 16, 2014)

1106-11-2752 **Pete L. Clark** and **Allan Lacy*** (alacy@math.uga.edu), Department of Mathematics, Boyd Graduate Studies Research Center, University of Georgia, Athens, GA 30602. *On the index of genus one curves over infinite, finitely generated fields.*
We show that every infinite, finitely generated field admits genus one curves with index equal to any prescribed positive integer. The proof is by induction on the transcendence degree. This generalizes – and uses as the base case of an inductive argument – an older result on the number field case. There is a separate base case in every positive characteristic p, and these use work on the conjecture of Birch and Swinnerton-Dyer over function fields. (Received September 16, 2014)

1106-11-2774 **M.Tip E. Phaovibul*** (phaovib1@illinois.edu), Department of Mathematics, 1409 W Green St, Urbana, IL 61801. *Extensions of Selberg-Delange Method.* Preliminary report.
The Selberg-Delange method is a method that is widely used to determine the asymptotic behavior of the sum of arithmetic functions whose corresponding Dirichlet's series can be written in the term of the Riemann zeta function. In this talk, we first provide a history and recent developments of the Selberg-Delange method. Then, we provide a generalized version of the Selberg-Delange method which can be applied to a larger class of arithmetic functions and some applications. (Received September 16, 2014)

1106-11-2785 **Sin Tsun Edward Fan*** (sfan@caltech.edu), CIT 253-37, 1200 E. California Blvd., Pasadena, CA 91125. *On Higher Etale Regulators and Application to Higher Class Field Theory.*
Regulator maps have been a central tool in the study of special values of L-functions. In this talk, we will address a new construction of regulator maps from the Etale motivic cohomology to the Deligne cohomology, which is compatible with Bloch's construction for higher Chow groups. This construction is done on the level of etale complexes, and it facilitates the definition of the etale motivic cohomology with compact support. In particular, an Artin-Verdier type duality is valid, and it provides a natural way to construct the Weil group for general finitely generated fields, which recovers some features of the class formations. We will also show that

divisible subgroups of the etale motivic cohomology vanishes under our regulator maps, this provides evidence of the conjectural existence of a duality theory on etale motivic cohomology. (Received September 16, 2014)

1106-11-2807 **Amita Malik*** (amalik10@illinois.edu), 1409 W Green Street, Urbana, IL 61801. *Parity results for t-core partitions.*

In this talk, we discuss some parity results satisfied by t-core partitions for certain values of t. These partitions also show up in representation theory and are interesting objects of study. The results discussed in this talk involve infinite families of congruences modulo 2. (Received September 16, 2014)

1106-11-2816 **Karl Mahlburg*** (mahlburg@math.lsu.edu), 228 Lockett Hall, Department of Mathematics, Baton Rouge, LA 70803. *Asymptotic behavior of distinct parts partitions without sequences.*

MacMahon initiated the study of partitions without sequences, which means that no consecutive integers occur as parts. This was later generalized to partitions without sequences of length k by Andrews and Holroyd-Liggett-Romik. In this talk I will present combinatorial and asymptotic results for partitions into distinct parts with short sequences. The case k=2 corresponds to the famous Rogers-Ramanujan partition identities. (Received September 16, 2014)

1106-11-2820 **Owen F. Barrett*** (owen.barrett@yale.edu), PO Box 202519, New Haven, CT 06520, and **Brian McDonald**, **Steven J. Miller**, **Patrick Ryan**, **Caroline L. Turnage-Butterbaugh** and **Karl Winsor**. *Gaps between zeros of* GL(2) *L-functions.*

Let $L(s, f)$ be an L-function associated to a primitive form f on GL(2) over $\mathbf{Q}$. Combining mean-value estimates from Montgomery and Vaughan with a method of Ramachandra, we prove a formula for the mixed second moment of derivatives of $L(1/2 + it, f)$ and use it to show that there are infinitely many gaps between consecutive zeros of $L(s, f)$ along the critical line that are at least $\sqrt{3}$ times the average spacing. Using general pair correlation results for primitive GL(2) L-functions, we also prove that there are infinitely many gaps between consecutive zeros of $L(s, f)$ along the critical line that are smaller than 0.83 times the average spacing. (Received September 16, 2014)

1106-11-2837 **D. Airey*** (dylan.airey@utexas.edu) and **B. Mance** (mance@unt.edu). *The Hausdorff dimension of sets of numbers defined by their Q-Cantor series expansions.*

Cantor series expansions are a generalization of b-ary expansions. Given a sequence $Q = (q_n)$ of integers greater than or equal to 2, the Q-Cantor series expansion of a real number x is the unique expansion of the form

$$x = E_0 + \sum_{n=1}^{\infty} \frac{E_n}{q_1 q_1 \cdots q_n}$$

where $E_0 = \lfloor x \rfloor$ and E_n is in $\{0, 1, \cdots, q_n - 1\}$ for $n \geq 1$ with $E_n \neq q_n - 1$ infinitely often.

Following in the footsteps of P. Erdős, A. Rényi, and T. Šalát we compute the Hausdorff dimension of sets of numbers whose digits with respect to their Q-Cantor series expansions satisfy various statistical properties. In particular, we consider difference sets associated with various notions of normality and sets of numbers with a prescribed range of digits. (Received September 16, 2014)

1106-11-2946 **Jared S Weinstein*** (jsweinst@math.bu.edu), Boston University, Department of Mathematics and Statistics, Boston, MA 02215. *Exploring the Galois group of the rational numbers: recent breakthroughs.*

It's a basic result that the polynomial $x^2 + 1$ factors modulo an odd prime p exactly when $p \equiv 1 \pmod 4$. Are there such rules governing the factorization of any polynomial modulo a prime? This question lies at the heart of algebraic number theory, which has roots extending back to Fermat and Gauss, and which is best phrased in terms of the Galois group of the rationals, $\mathrm{Gal}(\overline{\mathbf{Q}}/\mathbf{Q})$. There are (mostly open) conjectures which link this problem to the behavior of analytic objects known as automorphic forms. We will discuss these and also a recent breakthrough of Peter Scholze, who found a surprising connection between $\mathrm{Gal}(\overline{\mathbf{Q}}/\mathbf{Q})$ and the geometry of certain manifolds, called locally symmetric spaces. (Received September 17, 2014)

12 ► Field theory and polynomials

1106-12-966 **Nils Amend** and **Angela Berardinelli***, 1155 Union Circle #311430, Denton, TX 76203-5017, and **J. Matthew Douglass** and **Gerhard Roehrle**. *Invariants and Arrangements of Finite Complex Reflection Groups.*

Suppose that G is a finite unitary reflection group acting on a complex vector space V and X is a subspace of V. Define N and Z to be the setwise and pointwise stabilizers, respectively, of X in G. Then restriction from V to X defines a homomorphism from the algebra of G-invariant polynomial functions on V to the algebra of N/Z-invariant polynomial functions on X. In this talk I will describe a simple characterization of when this restriction mapping is surjective in terms of the exponents of G and N/Z and their reflection arrangements, in the case when X is in the lattice of the arrangement of G. This extends earlier work by Douglass and Roehrle when G is a Coxeter group. (Received September 09, 2014)

1106-12-1070 **Lou van den Dries*** (`vddries@math.uiuc.edu`), University of Illinois, Department of Mathematics, 1409 West Green St, Urbana, IL 61801. *Model theory of transseries.* Preliminary report.

This is a report on a collaboration with Matthias Aschenbrenner and Joris van der Hoeven. Last spring we finished a twenty year quest by finding and proving the key model-theoretic and algebraic facts about the differential field of transseries (in the spirit of Tarski's classical results about the logical properties of the field of real numbers). After outlining this work, I will discuss some problems about the differential algebra and model theory of transseries that are still open. (Received September 10, 2014)

1106-12-1713 **DoYong Kwon*** (`doyong@jnu.ac.kr`), Department of Mathematics, Chonnam National University, Gwangju, 500-757, South Korea. *Mahler measures and irreducible polynomials.*

Let $g(x) = a_n x^n + \cdots + a_1 x + a_0 = a_n \prod_{i=1}^n (x - \alpha_i) \in \mathbb{Z}[x]$ with $a_n \neq 0$. The Mahler measure of g is a real number ≥ 1 defined by $M(g) := |a_n| \prod_{i=1}^n \max\{1, |\alpha_i|\}$. In this talk, we demonstrate that the Mahler measure is employed to prove irreducibility of a certain class of polynomials over $\mathbb{Q}$. (Received September 15, 2014)

1106-12-2926 **Siyu Liu***, siyu@comm.utoronto.ca, and **Felice Manganiello** and **Frank R Kschischang**. *Skew Polynomials in Coding Theory.*

Skew polynomials are a noncommutative generalization of ordinary polynomials that, in recent years, have found applications in coding theory and cryptography. In this talk, we will present an overview of the recent advances in the applications of skew polynomials to coding theory. Some of our recent results, including skew interpolation and evaluation, will be highlighted. Ongoing works and potential new areas of research will be discussed. (Received September 17, 2014)

13 ► Commutative rings and algebras

1106-13-23 **Irena Peeva*** (`irena@math.cornell.edu`) and **David Eisenbud** (`de@msri.org`). *Matrix Factorizations and Complete Intersection Rings.*

Motivated by applications in Invariant Theory, Hilbert introduced an approach to describe the structure of modules by free resolutions. Hilbert's Syzygy Theorem shows that minimal free resolutions over a polynomial ring are finite. Most minimal free resolutions over quotient rings are infinite. We will discuss the properties of such resolutions. The concept of matrix factorization was introduced by Eisenbud 35 year ago, and it describes completely the asymptotic structure of minimal free resolutions over a hypersurface. Matrix factorizations have applications in many fields of mathematics: for the study of cluster algebras, Cohen-Macaulay modules, knot theory, moduli of curves, quiver and group representations, and singularity theory. Starting with Kapustin and Li, physicists discovered amazing connections with string theory. Recently, we introduced the concept of matrix factorization for complete intersection rings and showed that it suffices to describe the asymptotic structure of minimal free resolutions over complete intersections. (Received September 16, 2014)

1106-13-155 **Hannah Lee Altmann*** (`hannah.altmann@ndsu.edu`). *Semidualizing complexes over tensor products.* Preliminary report.

Let R be a commutative, noetherian ring with identity. A finitely generated R-module C is *semidualizing* if the homothety map $\chi_C^R : R \to \mathrm{Hom}_R(C, C)$ is an isomorphism and $\mathrm{Ext}_R^i(C, C) = 0$ for all $i > 0$. For example, R is semidualizing over R, as is a dualizing module, if R has one. In some sense the number of semidualizing modules gives a measure of the "complexity" of R. We are interested in that number. We will discuss constructing semidualizing modules over tensor products of rings over a field. In particular, this gives us a lower bound on the number of semidualizing modules over the tensor product. (Received July 31, 2014)

1106-13-165 **Jung Wook Lim*** (jwlim@knu.ac.kr), Department of Mathematics, Kyungpook National University, Daegu, 702-701, South Korea. *A generalization of strong Mori domains.*

Let D be an integral domain, S be a (not necessarily saturated) multiplicative subset of D, w be the so-called w-operation on D, and M be a unitary D-module. As generalizations of strong Mori domains and strong Mori modules, we define D to be an S-strong Mori domain if each nonzero ideal I of D, there exist an $s \in S$ and a w-finite type ideal J of D such that $sI \subseteq J \subseteq I_w$; and M to be an S-strong Mori module if M is a w-module and for each nonzero submodule N of M, there exist an $s \in S$ and a w-finite type submodule F of N such that $sN \subseteq F \subseteq N_w$. In this talk, we present some properties of S-strong Mori domains and S-strong Mori modules. (This is a joint work with H. Kim and M.O. Kim.) (Received August 04, 2014)

1106-13-559 **Jim Coykendall** (jcoyken@clemson.edu), Mathematical Sciences, Clemson University, Martin O-103, Clemsen, SC 29634, and **Richard Erwin Hasenauer*** (rhasenauer@eureka.edu), Eureka College, 300 E College, Eureka, IL 61530. *Factorization properties of Prüfer domains.*

A Prüfer domain will be said to be Archimedean if all of its local value groups are Archimedean. We will construct a norm N on the set of ideals of an Archimedean Prüfer domain using the surreal numbers, that satisfies the property that $N(IJ) = N(I) + N(J)$ for all ideals $I, J \subseteq D$. Turning our attention to Prüfer domains of finite character (every element is in only finitely many maximal ideals) we show that every ideal factors uniquely into a product of generalized prime powers. We also show that any atomic Prüfer domain of finite character is necessarily a bounded factorization domain. (Received September 02, 2014)

1106-13-613 **Jim Coykendall**, **Richard Hasenauer** and **Bethany Kubik*** (bethany.kubik@usma.edu). *Generalized Unique Factorization Domains.* Preliminary report.

We define a generalized unique factorization domain (GUFD) as a domain in which every element that factors does so uniquely. Given an irreducible element x in a ring R, we build four sets that are composed of elements whom x "acts prime on" with respect to either the set itself or R. We use these sets to help us understand the properties of GUFDs. (Received September 03, 2014)

1106-13-632 **Pye Phyo Aung*** (pye.aung@ndsu.edu). *Gorenstein Dimensions of Some Rings of the Form $R \oplus C$.*

Given a semidualizing module C over a commutative noetherian ring R, Holm and Jørgensen investigate some connections between C-Gorenstein dimensions of an R-complex M and Gorenstein dimensions of M viewed as a complex over the "trivial extension" $R \ltimes C$. We will discuss generalizations of some of their results to a certain type of retract diagram. We will also discuss some examples of such retract diagrams, namely D'Anna and Fontana's amalgamated duplication and Enescu's pseudocanonical cover. (Received September 07, 2014)

1106-13-654 **Craig Huneke*** (huneke@virginia.edu), Department of Mathematics, University of Virginia, Charlottesville, VA 22904. *The projective dimension of quadrics.*

This talk concerns Stillman's question which asks if the projective dimension of n forms of degrees $d_1, ..., d_n$ in a polynomial ring is bounded as a function of those degrees. We concentrate mainly on the case in which $d_i = 2$ for every i. Most of the talk will be on joint work with Jason McCullough, Paolo Mantero, and Alexandra Seceleanu. In particular we give a sharp bound when the height is 2. (Received September 04, 2014)

1106-13-688 **Sean Sather-Wagstaff** and **Jonathan Totushek*** (jonathan.totushek@ndsu.edu). *Finiteness of Homological Dimensions with Respect to a Semidualizing Complex.* Preliminary report.

A result of Foxby states: If there exists a complex with finite depth, finite flat dimension, and finite injective dimension over a local ring R, then R is Gorenstein. In this talk we will investigate some homological dimensions involving a semidualizing complex and improve upon Foxby's result by answering a question of Takahashi and White. In particular we prove for a semidualizing complex C, if there exists a complex with finite depth, finite $\mathcal{F}_C$-projective dimension, and finite $\mathcal{I}_C$-injective dimension over a local ring R, then R is Gorenstein. (Received September 04, 2014)

1106-13-814 **Lokendra P Paudel*** (lokendra@nmsu.edu), New Mexico State University, Las Cruces, NM 88001. *The Group of Divisibility of a Finite Intersection of Valuation Rings.*

The group of divisibility of an integral domain is the multiplicative group of nonzero principal fractional ideals of the domain. The goal of this presentation is to describe the lattice-ordered groups (ℓ-groups) that occur as a group of divisibility of an intersection of finitely many valuation overrings of the domain $D = k[x_1, x_2, ..., x_n]$, where k is a field and $x_1, x_2, ..., x_n$ are indeterminates for k. (Received September 07, 2014)

1106-13-883 **Gabriel E Sosa*** (gsosa@purdue.edu). *On the Koszulness of multi-Rees Algebras of certain strongly stable ideals.*

Generalizing techniques that prove that Veronese subrings are Koszul, we provide explicit quadratic Gröbner basis, with squarefree initial monomials, for the defining ideals of Rees and multi-Rees algebras of certain types of principal strongly stable ideals to show that they are Koszul, normal Cohen-Macaulay domains. (Received September 08, 2014)

1106-13-967 **Hailong Dao** and **William T Sanders*** (wsanders@ku.edu), 405 Snow Hall, 1460 Jayhawk Blvd, Lawrence, KS 66045. *Supports and Support Varieties.*

Developed by Avramov and Buchweitz, the theory of support varieties over a complete intersection ring encodes important homological information about a module into a geometric object. In this talk, we investigate the support variety of the tensor product of two modules using the geometry of the support varieties of the original modules. Furthermore, we study the relationship between the dimensions of modules and their tensor product, allowing us to relate the support variety of a module to its actual support. (Received September 09, 2014)

1106-13-984 **Luchezar Avramov**, **Courtney Gibbons** and **Roger Wiegand*** (rwiegand1@unl.edu). *Koszul modules over short graded Gorenstein rings.* Preliminary report.

Let k be a field and R a short, standard graded Gorenstein k-algebra. ("Short" means that $R = k \oplus R_1 \oplus R_2$.) When the embedding dimension $e := \dim_k R_1$ is three or more, R has wild representation type, but one can learn a lot about module structure by studying the semigroup of Betti diagrams of finitely generated R-modules. An important piece of the puzzle is the semigroup of Hilbert functions of Koszul modules. (These are the modules that are generated in degree zero and have linear resolutions.) In this talk I will describe this semigroup explicitly and say a little about its structure in semigroup-theoretic terms. (Received September 09, 2014)

1106-13-986 **Susan E. Morey*** (morey@txstate.edu), Department of Mathematics, Texas State University, 601 University Dr., San Marcos, TX 78666. *Using Parameters from Graph Theory to Bound Algebraic and Geometric Invariants of Edge Ideals.*

In recent years many exciting connections have been discovered between parameters in Graph Theory, Combinatorics, and Commutative Algebra. Given a graph or a simple hypergraph, also called a clutter, there is an associated square-free monomial ideal, called the edge ideal. This association induces a natural one-to-one correspondence between square-free monomial ideals and clutters. Using this correspondence, algebraic properties of ideals can be translated into graph theoretic or combinatorial properties and vice versa, thus allowing techniques from one field of mathematics to be used to answer questions from another. The focus of this talk will be on how parameters of a graph or hypergraph, such as the diameter, independence number, domination number, or matching number, relate to algebraic invariants of the edge ideal of the graph or hypergraph. The algebraic invariants presented will be of geometric interest, such as depth, projective dimension, and index of stability. (Received September 09, 2014)

1106-13-1239 **Arindam Banerjee***, ab4cb@virginia.edu. *Title:Linear Resolutions Of Monomial Ideals Related To Graphs.*

Abstract: This talk will discuss several classes of monomial ideals related to finite simple graphs which have linear minimal free resolutions. A special emphasis will be on the graphs whose complements do not have any induced four cycle . We will discuss some recent developments and some open problems. (Received September 11, 2014)

1106-13-1319 **Andreas Reinhart*** (andreas.reinhart@uni-graz.at), Karl-Franzens-Universität Graz, Institut für Mathematik, Heinrichstrasse 36, 8010 Graz, Styria, Austria. *On conductor ideals.*

Let S be a commutative ring with identity, R a subring of S, and I an ideal of S. We say that I is an R-conductor ideal of S, if $I = \{x \in S \mid xS \subseteq V\}$ for some intermediate ring V of R and S. $\mathbb{Z}$-conductor ideals have already been investigated by P. Furtwängler about a century ago. They have also been studied by G. Lettl and C. Prabpayak just recently. P. Furtwängler provided a characterization of $\mathbb{Z}$-conductor ideals of principal orders

in algebraic number fields. We generalize and rediscover his result by using the techniques of modern algebra. Moreover, we present sufficient criteria for being an R-conductor ideal of S. We show, for instance, that if S/I is Noetherian, $R/I \cap R$ is a principal ideal ring, and every $P \in \operatorname{spec}(S)$ with $I \subseteq P$ satisfies $R + P \subsetneq S$ or $\{x \in R \mid xP \subseteq I\} \subseteq I$, then I is an R-conductor ideal of S. We complement our results by presenting a few counterexamples. (Received September 12, 2014)

1106-13-1487 **Federico Galetto***, 48 University Avenue, Kingston, ON K7L 3N6, Canada. *On a family of equivariant resolutions.* Preliminary report.

For modules over polynomial rings with a reasonable group action, the minimal free resolution of the module inherits an action by the same group. Understanding how the group acts on the resolution leads to a refinement of classical invariants of the module, such as the Betti numbers and the Hilbert series. In this talk, I will present examples of resolutions with group actions and their connections with representation theory and geometry. (Received September 13, 2014)

1106-13-1524 **Adam Boocher**, **Alessio D'Ali** and **Jonathan Montaño*** (jmontano@purdue.edu), 150 N. University Street, West Lafayette, IN 47907, and **Eloisa Pires** and **Alessio Sammartano**. *Deviations of graded algebras.* Preliminary report.

Let $S = k[x_1, \ldots, x_n]$ be a polynomial ring over a field k and $R = S/I$ for some proper homogeneous S-ideal I. The deviations of R are the natural numbers $\{\varepsilon_i(R)\}_{i\geqslant 1}$, where $\varepsilon_i(R)$ is the number of variables added in the ith step in the construction of the minimal Tate resolution of k over R. These numbers completely determine the Poincaré series of k and measure how far is R from being regular or complete intersection. In this talk, I will report work in progress joint with A. Boocher, A. D'Ali, E. Pires, and A. Sammartano, where we study extremal deviations and the behavior of deviations in families of ideals. In addition, we compute a significant number of deviations for some class of edge ideals and use this information to explicitly find the minimal algebra generators of the Koszul homology of k over R. (Received September 13, 2014)

1106-13-1535 **David Eisenbud*** (de@msri.org), 17 Gauss Way, Berkeley, CA 94720. *Operators on resolutions over complete intersections.*

If $R = S/(f_1, \ldots, f_c)$ is a local complete intersection of codimension c, and M is a finitely generated R-module, then there are homotopy-commutative operators of homological degree -2 on the minimal R-free resolution of M that (for example) make

$$Ext^*_R(M, N) = Ext^{\text{even}}_R(M, N) \oplus Ext^{\text{odd}}_R(M, N)$$

into the direct sum of two finitely generated modules, the even and odd parts, over the ring generated by the operators.

It turns out that there are "higher" ci-operators, one of degree -m for every natural number m, that satisfy simple identities and give some information about the relation between the even and odd Ext modules above. I will explain this new development and the way that it is related to the resolution of M over S.

This is joint work with Irena Peeva and Frank-Olaf Schreyer (Received September 14, 2014)

1106-13-1538 **Paolo Mantero*** (mantero@math.ucr.edu), University of California at Riverside, and **Jason McCullough**, Rider University. *The projective dimension of an ideal generated by 3 cubic forms.* Preliminary report.

Let R be a polynomial ring over a field and I an ideal generated by three forms of degree three. Motivated by Stillman's question, Engheta proved that the projective dimension $\operatorname{pd}(R/I)$ is at most 36. Since the largest known example has $\operatorname{pd}(R/I) = 5$, for several years it has been asked what is the sharp upper bound for $\operatorname{pd}(R/I)$.

In this work we answer the question by showing that $\operatorname{pd}(R/I) \leq 5$ (which, by the above, is sharp). (Received September 14, 2014)

1106-13-1540 **Hailong Dao*** (hdao@ku.edu), Department of Mathematics, University of Kansas, Lawrence, KS 66045, and **Jay Schweig**, Department of Mathematics, Oklahoma State University, Stillwater, OK 74078. *Bounding projective dimension via domination parameters.*

Let I be an ideal in a polynomial ring R. The projective dimension is the shortest length of a projective resolution of I. When I is a squarefree monomial ideal, Hochster's Formula allows us to relate projective dimension of I and the homology of subcomplexes of an associated simplicial complex known as the Stanley-Reisner complex of I.

We start with the case when I is the edge ideal of a graph and show how graph domination parameters, invariants which measure how easy it is to "cover" a graph with various subgraphs, can be used to bound these invariants. Then we explain how some of these results generalize for any square free monomial ideal, and therefore any simplicial complex. (Received September 14, 2014)

1106-13-1565 **Alexandra Seceleanu*** (aseceleanu@unl.edu). *Using syzygies to test containments between symbolic and ordinary powers for some ideals of points.*

Symbolic powers of ideals play a significant part in algebraic geometry and in commutative algebra, where containment relations between symbolic powers and ordinary powers have become a focus of interest. This area has seen exciting new developments recently. It had been expected that $I^{(Nr-N-1)} \subseteq I^r$ should hold for the ideal I of any finite set of points in $\mathbb{P}^N$ and all $r > 0$, but in the last years various counterexamples to this conjecture have been constructed, some involving classical configurations of points that go back to Hesse and Klein. My talk will describe a homological criterion to detect the failure of the containment of the symbolic cube in the square of some ideals defining reduced sets of points in the projective plane (the case $N = r = 2$), that can be applied to these counterexamples. (Received September 14, 2014)

1106-13-1576 **Sandra Spiroff*** (spiroff@olemiss.edu), Department of Mathematics, P.O. Box 1848, Hume Hall 335, University, MS 38677, and **Sean Sather-Wagstaff**. *On the structure of S_2-ifications of complete local rings.* Preliminary report.

We discuss several constructions related to the S_2-ification of a complete equidimensional local ring, with emphasis on the "Hochster-Huneke graph". (Received September 14, 2014)

1106-13-1730 **Mark Batell*** (mbatell@uco.edu). *Factorization in Mori Domains.* Preliminary report.

Let R be an integrally closed Mori domain. It is well-known in this case that R^*, the complete integral closure of R, is a Krull domain. Therefore, it is natural to ask whether certain factorization properties of R can be ascertained by passing to the complete integral closure R^*. For example, using this strategy we can show that if R is an integrally closed Mori domain, then R is a BFD. Also, R is an FFD if and only if $U(R) = U(R^*)$. (Received September 15, 2014)

1106-13-1757 **Dylan C Rupel*** (d.rupel@neu.edu), 567 Lake Hall, Department of Mathematics, Northeatern University, Boston, MA 02115. *A modified combinatorics for greedy bases.*

I will begin with a recursive description of greedy bases in rank 2 generalized cluster algebras. To see that these recursions terminate one uses the combinatorics of compatible sets of weights on a maximal Dyck path, I will introduce in this talk a topological way to view these compatible sets of weights as collections of arcs in a punctured disk with weighted boundary points. Time permitting I will discuss a natural partial ordering on these collections of arcs and an application toward understanding noncommutative rank 2 generalized cluster variables. (Received September 15, 2014)

1106-13-1800 **Thomas Marley*** (tmarley1@unl.edu) and **Marcus Webb**. *Artinian modules of finite flat dimension and the Frobenius functor.*

We investigate the behavior of the Frobenius functor on Artinian modules over a d-dimensional Noetherian local ring R of characteristic $p > 0$. Let R^f denote the ring R equipped with an $R-R$ bimodule structure whose left action is via the identity map and whose right action is via the Frobenius map from R to R. We let F_R denote the functor $R^f \otimes_R -$. For an Artinian module M, let $s(M)$ denote the least integer i such that $\operatorname{Tor}_i^R(R/m, M) \neq 0$. One of our main results is the following:

Theorem 0.1. *Let M be a nonzero Artinian R-module. The following are equivalent:*

(1) $\operatorname{Tor}_i^R(R/m, M)$ *is zero for all but one integer i.*

(2) $F_R(M) \cong M$ *and* $\operatorname{Tor}_i^R(R^f, M) = 0$ *for* $1 \leq i \leq s(M)$.

(3) R *is Cohen-Macaulay and* $M \cong H_m^d(R)^n$ *for some* $n > 0$.

(4) $F_R(M) \cong M$ *and M has finite flat dimension.*

In this talk, we will discuss this theorem and several related results. (Received September 15, 2014)

1106-13-1856 **Idan Eisner*** (eisner@math.haifa.ac.il). *Exotic cluster structures on SL_n with Belavin-Drinfeld data of minimal size.*

Cluster algebras were introduced by Fomin and Zelevinsky in 2001. They are commutative rings, with a distinguished set of generators that are grouped into overlapping finite sets of the same cardinality. Among many other examples, cluster algebras appear in coordinate rings of various algebraic varieties. Using the notion of compatibility between Poisson structures and cluster algebras, Gekhtman Shapiro and Vainshtein conjectured that for a simple complex Lie group G, there is a correspondence between Poisson - Lie structures on G and cluster structures in $\mathcal{O}(G)$. Poisson - Lie groups can be classified through the Belavin - Drinfeld classification of solutions to the classical Yang - Baxter equation. The conjecture suggests a one to one correspondence between Belavin - Drinfeld classes and cluster structures in $\mathcal{O}(G)$. It has been proved for $G = SL_n$ where $n < 6$, for the Cremmer - Gervais case in SL_n for any n, and for the standard case for any G. Given a Belavin - Drinfeld data of type $\alpha \mapsto \beta$ in SL_n, we describe an algorithm to construct a cluster structure $\mathcal{C}$ that is compatible with the corresponding Poisson bracket $\{\cdot,\cdot\}_{\alpha\beta}$ and show that the conjecture holds in this case. (Received September 15, 2014)

1106-13-1935 **Christine Berkesch Zamaere*** (cberkesc@math.umn.edu), University of Minnesota, Minneapolis, MN, **Daniel Erman**, University of Wisconsin, Madison, WI , and **Gregory G. Smith**, Queen's University, Kingston, Ontario. *Free complexes on smooth toric varieties.*

I will discuss work in progress related to strengthening homological tools over Cox rings of smooth toric varieties. (Received September 15, 2014)

1106-13-2089 **Uwe Nagel** and **Bill Robinson*** (robinsonwm@uky.edu). *Gorenstein Liaison of Skew Tableau Ideals.*

Skew tableau ideals are generated by minors in a subregion of a matrix of indeterminates called a skew tableau. We will discuss the classification of these ideals using Gorenstein linkage and present recent progress in the study of ideals generated from a symmetric version of skew tableaux. This is joint work with Uwe Nagel. (Received September 15, 2014)

1106-13-2323 **Emilie Dufresne** and **Jack Jeffries*** (jeffries@math.utah.edu). *How many invariants are needed to separate orbits?*

The study of separating invariants is a relatively recent trend in invariant theory. For a finite group acting linearly on a vector space, a separating set is a set of invariants whose elements separate the orbits of the action. In some ways, separating sets often exhibit better behavior than generating sets for the ring of invariants. We investigate the least possible cardinality of a separating set for a given action. Our main result is a lower bound which generalizes the classical result of Serre that if the ring of invariants is polynomial, then the group action must be generated by pseudoreflections. We find these bounds to be sharp in a wide range of examples. (Received September 16, 2014)

1106-13-2372 **Kiyoshi Igusa**, Waltham, MA, **Kent Orr**, Blumington, IN, **Gordana Todorov*** (g.todorov@neu.edu), Boston, MA 02115, and **Jerzy Weyman**, Storrs, CT. *Picture groups and Cluster theory.* Preliminary report.

To each modulated quiver Q of finite Dynkin type we associate a "picture" defined using domains of semi-invariants (stability conditions). To each such picture we associate a group $G(Q)$, called "picture group". Also, to the quiver Q we associate a cubical category $C(Q)$, called "cluster morphism category", which is defined in terms of wide subcategories and cluster tilting objects. Denote the classifying space of the cluster morphism category by $X(Q)$. We show that the space $X(Q)$ is $K(\pi, 1)$, i.e. has only one non-zero homotopy group π_1, and furthermore this group is isomorphic to the picture group $G(Q)$.

In another paper we also show that maximal green sequences correspond to positive expressions of Coxeter in the picture group $G(Q)$. (Received September 16, 2014)

1106-13-2399 **Florian Enescu** and **Sara L. C. Malec*** (smalec@pacific.edu), 3601 Pacific Ave, Stockton, CA 95207. *Intersection algebras for principal monomial ideals in polynomial rings.*

The intersection algebra of two ideals in a commutative Noetherian ring is a natural concept which is presently poorly understood. Results are obtained regarding the Hilbert series and the canonical ideal of the intersection algebra using methods from the theory of diophantine linear equations with integer coefficients. (Received September 16, 2014)

1106-13-2519 **Andrey Minchenko*** (an.minchenko@gmail.com). *Hopf algebras of reductive differential algebraic groups.*

Linear differential algebraic groups (LDAGs) arise as Galois groups of systems of linear partial differential equations. An important problem of the differential Galois theory is to describe such a group algorithmically, staring from the system of equations. The dual object to a LDAG is a differentially finitely generated commutative differential Hopf algebra. One can define reductive LDAGs and study corresponding Hopf algebras using natural filtrations on them. We will see how remarkable properties of such algebras lead to an algorithm that answers the question whether the Galois group is reductive or not. The talk is based on a joint paper with Alexey Ovchinnikov and Michael Singer. (Received September 16, 2014)

1106-13-2560 **Michael DiPasquale*** (dipasqu1@illinois.edu), Department of Mathematics, 1409 W. Green Street, Urbana, IL 61801. *Castelnuovo-Mumford Regularity of Mixed Spline Spaces.* Preliminary report.

We give a combinatorial bound on the Castelnuovo-Mumford regularity of the algebra $C^\alpha(\mathcal{P})$ of piecewise polynomial functions on a central polytopal complex $\mathcal{P}$ with mixed smoothness parameters when $C^\alpha(\mathcal{P})$ has low projective dimension. We accomplish this bound via an approximation of $C^\alpha(\mathcal{P})$, an approach inspired by the proof of the Gruson-Lazarzfeld-Peskine bound for the regularity of curves embedded in projective space.

As a consequence, we bound the degrees d for which the Hilbert polynomial of $C^\alpha(\mathcal{P})$, computed by Billera, Schenck, Geramita, and McDonald, gives the correct dimensions of the corresponding space of splines of degree d. This recovers and extends previously known estimates from the approximation theory side of the story. (Received September 16, 2014)

1106-13-2608 **Gwyneth R Whieldon*** (whieldon@hood.edu), Hood College, Department of Mathematics, 401 Rosemont Ave, Frederick, MD 21701, and **Jill Bigley Dunham** (jillbd@gmail.com). *Strongly Generic Artinian Monomial Ideals and Upper Intervals in the Weak Bruhat Order.* Preliminary report.

In this talk, we illustrate a connection between strongly generic, trivariate Artinian monomial ideals containing $\{x^{n+1}, y^{n+1}, z^{n+1}\}$ in their minimal generating set and upper intervals in the weak Bruhat order on permutations S_n. Considering monomial ideals that are strongly generic (given any pair of generating monomials m and m', if a variable divides both generators it must do so to different powers) and Artinian, we create a bijection between degree-minimal examples of such ideals $M_{\sigma,\tau}$ and pairs of permutations $\sigma, \tau \in S_n$ with complementary sets of inversions, e.g. permutations such that $\mathrm{Inv}(\sigma) \cup \mathrm{Inv}(\tau) = \{(i,j) : 1 \leq i < j \leq n\}$. For such an ideal $M_{\sigma,\tau}$, we produce the Buchberger graph $B(M_{\sigma,\tau})$ supporting the resolution of the monomial ideal $M_{\sigma,\tau}$ in terms of permutations σ, τ, and examine how inserting a new generator $m \mapsto M_{\sigma,\tau}$ affects this graph. (Received September 16, 2014)

1106-13-2646 **Aaron N Brookner*** (brookner@mit.edu), 58 Manchester Rd., Brookline, MA 02446, and **David Corwin**, **Steven V Sam** and **Pavel Etingof**. *On the Cohen-Macaulayness of S_n-Invariant Subspace Arrangements.*

If we let $\lambda = (\lambda_1, \ldots, \lambda_r)$ be a partition of an integer n, we can define a certain subspace E_λ of $\mathbb{C}^n$. We then consider $X_\lambda = S_n \cdot E_\lambda$, the union of S_n-translates of E_λ, which is an algebraic variety. This talk is concerned with addressing the question: for which λ are X_λ or X_λ/S_n Cohen-Macaulay?

While we still lack a complete answer to this question, using representation theory of Cherednik algebras, standard commutative algebra, and computations in the Macaulay2 programming language, we have reached many partial results, including a definite "no" in the case that λ has at least four distinct parts. We also formulate a number of conjectures, and give evidence for a more general claim that X_λ is rarely ever Cohen-Macaulay, and when it is, there is some additional structure behind it coming from representation theory and integrable systems. (Received September 16, 2014)

1106-13-2910 **Jennifer Biermann*** (jbierman@mtholyoke.edu) and **Adam Van Tuyl**. *Generalized edge and cover ideals.* Preliminary report.

We generalize the notion of the edge ideal to a t-edge ideal whose minimal monomial generators consist of a vertex and t of its neighbors. We study the algebraic properties of the t-edge ideal as well as the combinatorial properties of the associated Stanley-Reisner simplicial complex. (Received September 17, 2014)

14 ► Algebraic geometry

1106-14-510 **Ellen J Goldstein*** (ellen.goldstein@bc.edu), Department of Mathematics, Carney Hall, Room 301, Boston College, Chestnut Hill, MA 02467. *A generalization of Young diagrams.*

It is well known that an endomorphism X of a finite dimensional vector space V over an algebraically closed field K is determined by its Jordan normal form up to conjugation by $\mathrm{GL}(V)$. If X acts nilpotently, we obtain from the sizes of the Jordan blocks a partition of $n = \dim V$ and thus a Young diagram corresponding to the conjugacy class of X. We present a generalization of Young diagrams, called ab-diagrams, that classify pairs (A, B) of linear maps between vector spaces U and V. These have been used to study the geometry of nilpotent orbit closures in the classical groups, most recently by the author in generalizing to prime characteristic results of Kraft and Procesi regarding the normality of nilpotent orbit closures in the orthogonal and symplectic groups. Time permitting, we will see how quivers can be used to classify so-called *orthosymplectic nilpotent pairs* in this setting. (Received August 31, 2014)

1106-14-593 **Turchetti Daniele*** (daniele.turchetti@imj-prg.fr). *Lifting Galois covers to characteristic zero with non-Archimedean analytic geometry.* Preliminary report.

Let k be an algebraically closed field of characteristic $p > 0$ and R a complete discrete valuation ring of characteristic zero, with residue field k. The thread of this talk are lifting problems, that ask what algebraic objects defined over k can be obtained by reduction of algebraic objects over R.

We focus on the problem of lifting G-Galois covers of curves explaining how we can get necessary and sufficient conditions when G is cyclic with the use of non-Archimedean analytic methods. Then we discuss how this approach opens new perspectives in the deformation theory of torsors over R, and in the arithmetic of fundamental groups in mixed characteristic. (Received September 03, 2014)

1106-14-682 **Justin Allman*** (allmanjm@wfu.edu) and **Richard Rimanyi**. *An iterated residue perspective on stable Grothendieck polynomials.* Preliminary report.

Grothendieck polynomials are important objects in the study of the K-theory of flag varieties. They exhibit many remarkable properties which have been studied in the context of algebraic geometry and tableaux combinatorics. We introduce a new tool, similar to generating sequences, which we call the iterated residue technique. As an application, we give a new proof that the Pieri rule for stable Grothendieck polynomials exhibits alternating signs. (Received September 04, 2014)

1106-14-1082 **Taylor Dupuy*** (dupuy@math.ucla.edu), Einstein Institute of Mathematics, Edmond J. Safra Campus, Givat Ram, The Hebrew University of Jerusalem, 91904 Jerusalem, Israel. *Differential Algebra Meets Derived Categories.*

I will talk about instances where the Derived Category formalism naturally solves problems in Differential Algebraic Geometry. This work began during the Spring 2014 semester at MSRI. Some of what I talk about is joint work J. Freitag and A. Royer. (Received September 10, 2014)

1106-14-1104 **Sarah E Anderson*** (sarah5@g.clemson.edu). *Applications of algebraic geometry to polar coding.*

In recent groundbreaking work, Arikan developed polar codes as an explicit construction of symmetric capacity achieving codes for binary discrete memoryless channels with low encoding and decoding complexities. A specific 2×2 binary kernel matrix G is considered, and $G^{\otimes n}$ is used to create 2^n new channels. As the number of channels grows, each channel becomes either a noiseless channel or a pure-noise channel, and the rate of this polarization is related to the kernel matrix used. Since Arikan's original construction, polar codes have been generalized to q-ary discrete memoryless channels, where q is a power of a prime, and other matrices have been considered as kernels. In our work, we expand on the ideas of Mori and Tanaka and Korada and Şaşoğlu by employing algebraic geometric codes to produce kernels of polar codes, specifically codes from maximal and optimal function fields. (Received September 16, 2014)

1106-14-1154 **Caryn Werner*** (cwerner@allegheny.edu), Department of Mathematics, Allegheny College, Meadville, PA 16335. *Surfaces of general type with $K^2 = 2\chi - 1$.*

We classify minimal algebraic surfaces of general type having $K^2 = 2\chi - 1$ and $\chi \geq 7$. Such surfaces are regular with canonical map of degree one or two. When the geometric genus is at least 13, the surface is a genus-two fibration. Otherwise we use the canonical map to describe these surfaces as birational either to the canonical image, or to a double cover of a rational surface. (Received September 11, 2014)

1106-14-1440 **Rostam Sabeti*** (rsabeti@olivetcollege.edu), Mathematics and Computer Science Department, Olivet College, 312 S. Main Street, Olivet, MI 49076. *Homogeneity of order m and Completeness in $K[x_1, \cdots, x_n]$.* Preliminary report.

For positive integer m and K an algebraically closed field, one may define a grading on $K[x_1, \cdots, x_n]$ that depends on m and leads to a concept of homogeneity of order m. We also introduces complete forward (backward) monomials. On applying Buchberger's Algorithm for finding `grl` Gröbner basis of some ideals, the above setting highly reduces the process toward new results. (Received September 13, 2014)

1106-14-1442 **Mee Seong Im*** (mim2@illinois.edu), 250 Altgeld Hall, 1409 West Green Street, Urbana, IL 61801. *Quiver Hecke algebras and filtered quiver representations.*

Khovanov-Lauda-Rouquier (KLR) algebras are prominent in the study of categorification of quantum groups. I will discuss how quiver Hecke algebras are related to a generalization of quiver representations and give results, further linking the two. I will give open conjectures, suggesting research. (Received September 13, 2014)

1106-14-1531 **Rekha R Thomas*** (rrthomas@uw.edu), Department of Mathematics, Box 354350, University of Washington, Seattle, WA 98195. *Algebra and Geometry in Computer Vision.*

In this talk I will describe recent work in the area of multiview geometry, a sub-discipline of computer vision, that makes use of methods from algebraic geometry, optimization and computational algebra. All of these problems are concerned with the reconstruction of three-dimensional scenes from (possibly noisy) images of the scene in known, unknown or partially known cameras. This body of work is joint with Sameer Agarwal, Chris Aholt, Hon-Leung Lee and Bernd Sturmfels. (Received September 13, 2014)

1106-14-1838 **Holly Krieger*** (hkrieger@math.mit.edu). *Unlikely intersections in complex dynamics.*

I will present an analogue, proposed by Baker-DeMarco, of the André-Oort conjecture applicable to moduli spaces of dynamical systems. I will discuss progress on this conjecture and some connections to model theory with unlikely intersection problems in complex dynamics. (Received September 15, 2014)

1106-14-1906 **Jordan S Ellenberg*** (ellenber@math.wisc.edu), University of Wisconsin, Department of Mathematics, 480 Lincoln Drive, Madison, WI 53705. *Random Selmer groups over function fields.*

I will discuss some questions around heuristics for Selmer groups of random elliptic curves proposed by Poonen and Rains and refined by Bhargava, Kane, Lenstra, Poonen, and Rains. In particular, I will discuss some interesting geometry questions (especially monodromy questions) that arise when these questions are considered over the field $\mathbf{F}_q(t)$. I also hope to talk about situations where the presence of rational torsion makes Selmer groups deviate from Poonen-Rains behavior, as in the work of Klagsbrun and Lemke Oliver. Work discussed is joint with Chris Hall, Zev Klagsbrun, and maybe some other people, depending on what happens between now and January. (Received September 15, 2014)

1106-14-1983 **Nathaniel Bushek*** (bushek@unc.edu), Department of Mathematics, UNC-Chapel Hill, CB # 3250, Phillips Hall, Chapel Hill, NC 27599. *Descent of line bundles to the GIT quotients $(G/B \times G/B \times G/B)//G$.*

Let G be a simple, connected, algebraic group over $\mathbb{C}$, B a Borel subgroup, and $T \subset B$ a maximal torus. Let Q be the root lattice, Λ the weight lattice, and d the least common multiple of the coefficients of the highest root θ of $\mathfrak{g}$ written in terms of the simple roots. Consider the diagonal action of G on the projective variety $X = G/B \times G/B \times G/B$. Then, for any triple (λ, μ, ν) of dominant integral weights there is a G-linearized line bundle $\mathcal{L}$ on X. Such a line bundle is said to descend to the GIT quotient $\pi : X(\mathcal{L})^{ss} \to X(\mathcal{L})//G$ if there exists a line bundle $\hat{\mathcal{L}}$ on $X(\mathcal{L})//G$ such that $\mathcal{L}\mid_{X(\mathcal{L})^{ss}} \cong \pi^*\hat{\mathcal{L}}$. We show $\mathcal{L}$ descends if $\mu, \nu \in d\Lambda$ and $\lambda + \mu + \nu \in dQ$. These conditions are useful in describing how the tensor product multiplicity $\dim[V(\lambda) \otimes V(\mu) \otimes V(\nu)]^G$ varies with respect to the triple (λ, μ, ν). (Received September 15, 2014)

1106-14-2252 **Marie Kelly Mauhar*** (marie.mauhar@my.lr.edu), 157 Chestnut Ridge Rd., Mills River, NC 28759. *H-Representation of the Kimura-3 Polytope.*

Given a group-based Markov model on a tree, one can compute the vertex representation of a polytope which describes the associated toric variety. The half-space representation, however, is not easily computable. In the case of $\mathbb{Z}$ or $\mathbb{Z}_2 \times \mathbb{Z}_2$, these polytopes have applications in the field of phylogenetics. We provide a half-space representation for the m-claw tree where $G = \mathbb{Z}_2 \times \mathbb{Z}_2$, which corresponds to the Kimura-3 model of evolution. (Received September 16, 2014)

1106-14-2328 **Corey S Harris*** (charris@math.fsu.edu), 208 Love Building, 1017 Academic Way, Tallahassee, FL 32306. *A method for computing Segre classes in arbitrary projective schemes.* Preliminary report.

We give an algorithm for computing Segre classes of subschemes of arbitrary projective schemes. The algorithm relies on computing a contribution of the subscheme to the degree of the ambient scheme (embedded in projective space) and comparing this with the results from taking successive hyperplane sections. The result of these computations is a linear system of equations which determines the coefficients of the Segre class pushed forward to projective space. To our knowledge, this is the first algorithm to be able to compute Segre classes at large, in ambient schemes other than projective space or toric varieties. One application is that the algorithm may be used to implement a routine for computing intersection products of projective schemes. (Received September 17, 2014)

1106-14-2476 **Sarah E Anderson*** (sarah5@g.clemson.edu). *Multipoint kernels for polar coding.*
Polar coding is a breakthrough method for an explicit construction of symmetric capacity achieving codes for discrete memoryless channels with low encoding and decoding complexities. The construction relies on a matrix called the kernel, and the exponent of the kernel provides an estimate of the decoding error probability. In this talk, we discuss the role of multipoint codes in polar coding and associated exponents. (Received September 16, 2014)

1106-14-2562 **Eric M. Hanson*** (hanson@math.colostate.edu), Department of Mathematics, 1874 Campus Delivery, Fort Collins, CO 80525. *Unit Distance Embeddings of Graphs via Numerical Algebraic Geometry.*
A unit-distance graph is a graph that can be embedded in $\mathbb{R}^2$ with unit length edges. Suppose (x_i, y_i) and (x_j, y_j) are adjacent vertices in a graph, then in order for the graph to be a unit-distance graph $(x_i - x_j)^2 + (y_i - y_j)^2 - 1 = 0$ for all adjacent vertices. With these equations, techniques from numerical algebraic geometry can be used to test if a graph has a unit-distance embedding. In particular, we consider the Heawood Graph, which is known to have 11 unit-distance embeddings (Gerbracht). We show that there are in fact infinitely many unit-distance embeddings. Since the Heawood Graph is the point-line incidence graph of the Fano Plane, our results further disprove Chvátal's conjecture that all point line incidence graphs of finite projective planes are not unit-distance graphs. (Received September 16, 2014)

1106-14-2568 **Leah A. Balay-Wilson*** (lbalaywi@smith.edu), **Yixin Bao** and **Hana Foe**. *Exploring Adinkras and Clifford Algebra representations.*
In this research, we constructed a family of graphs that we called oriented chromotopologies. The adjacency matrices of these graphs correspond to representations of $Cl(0, m)$, a subset of the Clifford algebras. As these Clifford algebra representation matrices can be large, the graphs can significantly shorten computational time.

A different family of graphs called adinkras have previously been used for the same purpose with $Cl(n, 0)$. Prior research has linked adinkras to set error-correcting codes. We show a method of deriving oriented chromotopologies from the same types of codes used for adinkras, and in fact a more general set of error-correcting codes. We then define a series of operations on oriented chromotopologies that correspond to specific basis changes in the adjacency matrices. This allows oriented chromotopologies to serve as a graphical method for showing isomorphism between representations. We then present a series of novel proofs to legitimize these operations. (Received September 16, 2014)

1106-14-2727 **Laura Escobar*** (le78@cornell.edu), Ithaca, NY 14853. *Bott-Samelson varieties, subword complexes and associahedra.*
In this talk we will define three objects: Bott-Samelson varieties, subword complexes and brick polytopes. More importantly we will discuss how these objects are connected: the moment polytope of a fiber of the Bott-Samelson map is the Brick polytope. In particular, we give a description of the toric variety of the associahedron in terms of flags arranged in a poset. (Received September 16, 2014)

1106-14-2731 **Jason A. Miller*** (millerj@math.osu.edu). *Okounkov Bodies of Borel Orbit Closures.*
The theory of Okounkov bodies generalizes the relationship between toric geometry and polytopes. The theory associates to a valuation v and line bundle $\mathcal{L}$ on a projective variety, a convex body $\Delta_v(\mathcal{L})$, which encodes information about the variety and line bundle. Spherical varieties are a generalization of certain classes of varieties with group actions such as toric and flag varieties. For such varieties, Okounkov theory can be used to obtain information about the G-orbits via faces on an associated polytope. However, much of the structure of these varieties is determined by the Borel orbit structure, which is generally not well understood. I will discuss original work examining an extension of this correspondence for a certain class of spherical varieties, wonderful group compactifications. Given any Borel orbit closure Z of a wonderful group compactification, the Okounkov construction gives a finite union of faces of the Okounkov polytope. This correspondence enjoys similar properties as in the case of G-orbits. The dimension of the space of global sections $H^0(Z, \mathcal{L})$ is given by the number of lattice points in the union of faces. One can then calculate the degree of $\mathcal{L}$ by taking the sum of the volume of these faces. (Received September 16, 2014)

1106-14-2778 **Yunyi Shen*** (yshen2@math.fsu.edu), Tallhassee, FL 32306. .
In this article, we propose a way of seeing the noncommutative tori in the category of noncommutative motives. As an algebra, the noncommutative torus is lack the smoothness property required to define a noncomutative

motive. Thus, instead of working with the algebra, we work with the category of holomorphic bundles. It is known that these are related to the coherent sheaves of an elliptic curve. We describe the cyclic homology of the category of holomorphic bundle on a noncommutative torus. We then introduce a notion of (weak) t-structure in dg categories. By applying the t-structure to a noncommutative torus, we show that it induces a decomposition of the motivic Galois group of the Tannakian subcategory generated by the auxiliary elliptic curve.
(Received September 16, 2014)

1106-14-2924 **Akhil Matthew*** (amathew@math.berkeley.edu), University of California, Berkeley, CA.
Descent for ring spectra and applications.

In derived algebraic geometry, there is a class of morphisms of ring spectra for which the conclusion of Grothendieck's faithfully flat descent theorem holds but which do not superficially (e.g., at the level of homotopy groups) appear to be faithfully flat. I will discuss this class of morphisms and some examples from stable homotopy theory and modular representation theory, and give an application to constructing a derived version of the étale fundamental group. (Received September 17, 2014)

15 ► Linear and multilinear algebra; matrix theory

1106-15-20 **Daniel A. Spielman*** (dan.spielman@gmail.com). *Graphs, vectors, and matrices.* Preliminary report.

No text available. (Received April 28, 2014)

1106-15-195 **Jorin S Schug*** (jschug1@swarthmore.edu). *Minimum Rank of Graphs with Zero Diagonal.* Preliminary report.

Given a graph, we can associate a family of zero-diagonal real symmetric matrices with it using the same nonzero pattern as the graph's adjacency matrix. The zero-diagonal minimum rank of the graph is the minimum of the ranks of all the associated matrices. In this talk, we will find the zero-diagonal minimum rank of several families of graphs, and discuss a theorem that calculates the zero-diagonal minimum rank of a cone on a graph. We will also give some applications of that theorem. (Received August 08, 2014)

1106-15-196 **Oscar F Leong*** (oleong1@swarthmore.edu). *Ranks of graphs over $\mathbb{Z}_2$.* Preliminary report.

We define the $\mathbb{Z}_2$-rank of a graph G to be the rank of its adjacency matrix over $\mathbb{Z}_2$. We show that the $\mathbb{Z}_2$-rank of G is full if and only if the graph G has an odd number of perfect matchings. We then compute the rank of G over $\mathbb{Z}_2$ for a number of different graph families, including paths, cycles, wheels, complete graphs, complete bipartite graphs, and ladder graphs. (Received August 08, 2014)

1106-15-267 **Paul R. Bouthellier*** (pbouthe@pitt.edu), 504 East Main Street, Titusville, PA 16354.
Matrices, Quaternions, Rotations, and Orientation in R3.

In this talk paths along which objects travel will be created by parametric curves in R2 and R3. The parametric curves are based on Bezier curves and polar equations. The orientation of the objects along the paths will then be created by using rotation matrices and quaternions. Problems with the orientation of the objects along paths, such as Gimbal lock and wrap-around infinities will then be studied. Gimbal lock occurs when a rotation about one axis causes a loss of ability to rotate about one of the three coordinate axes. Wrap-around infinities occur where the x, y, or z partial derivatives along the path become undefined. As orientations are based on the inverse tangent, an object can perform a rotation from –pi to pi or pi to –pi at such points. A problem where both Gimbal lock and wrap-around infinity occurred in actual practice will be illustrated. Techniques for dealing with Gimbal lock and wrap-around infinities will be discussed. The concepts discussed will be illustrated using the 3D graphics packages Studio 3D Max, Carrara, Poser and the programming language Python. (Received August 17, 2014)

1106-15-661 **Rachel Domagalski*** (domag1rj@cmich.edu), **Hong Suh** and **Xingyu Zhang**. *Tight Frame Structure and Scalability.* Preliminary report.

In $\mathbb{R}^n$, a frame is defined to be a spanning set. A collection $F = \{f_i\}_{i=1}^k \subseteq \mathbb{R}^n$ is a λ-tight frame if there exists $\lambda > 0$ such that for every $f \in \mathbb{R}^n$, $\lambda\|f\|^2 = \sum_{i=1}^k |\langle f, f_i\rangle|^2$. We examine the structure of frames through factor posets and scalability. A factor poset for a frame $F = \{f_i\}_{i=1}^k$ is the set $P = \{J \subseteq \{1, \dots, k\} : \{f_j\}_{j\in J}$ is a tight frame$\}$, partially ordered by set inclusion, $\emptyset \in P$. This definition leads to the question: given a poset P, when is P a factor poset? We call this problem the *inverse factor poset problem* (IFPP). The IFPP was solved in $\mathbb{R}^2$ in 2013. In our goal of solving the IFPP in $\mathbb{R}^n$, we discovered combinatorial properties of tight frames and explored constructions of frames from posets. Next, we examine the scalability of frames. For a frame $F = \{f_i\}_{i=1}^k$, a scaling is a vector $w = (w(1), \ldots, w(k)) \in \mathbb{R}_{\geq 0}^k$ such that $\{\sqrt{w(i)} f_i\}_{i=1}^k$ is a 1-tight frame in $\mathbb{R}^n$. We establish results on the structure of the scalability polytope and its connection to the factor poset. This research completed at Central Michigan University's 2014 REU. (Received September 04, 2014)

1106-15-703 **Hayoung Choi*** (hchoi2@uwyo.edu), Ross Hall, Room 205, 1000E. University Ave., Dept. 3036, Laramie, WY 82071, and **Farhad Jafari** (fjafari@uwyo.edu), Ross Hall, Room 229, 1000 E. University Ave., Dept. 3036, Laramie, WY 82071. *The Hamburger Moment Completion Problem.* Preliminary report.

In this paper we give solutions to the Hamburger moment problems with missing entries. The problem of completing a partially positive sequence to the Hamburger moment sequence in several variables is considered. The main result is a characterization of the Hamburger moment completable patterns in several variables, namely specified entries with certain patterns guarantee the existence of a Hamburger moment completion of a partially positive sequence. Moreover, conditions are given to complete certain patterns when these patterns are not completable. (Received September 04, 2014)

1106-15-710 **Stephan Ramon Garcia***, Department of Mathematics, Pomona College, 610 N. College Ave, Claremont, CA 91711. *On a problem of Halmos: unitary equivalence of a matrix to its transpose.*

Halmos asked whether every square complex matrix is unitarily equivalent to its transpose (UET). Ad hoc examples indicate that the answer is no. In this talk, we give a complete characterization of matrices which are UET. Surprisingly, the naïve conjecture that a matrix is UET if and only if it is unitarily equivalent to a complex symmetric (i.e., self-transpose) matrix is true in dimensions $n \leq 7$ but false for $n \geq 8$. In particular, unexpected building blocks begin to appear in dimensions 6 and 8. This is joint work with James E. Tener. (Received September 05, 2014)

1106-15-767 **Leslie Hogben*** (hogben@aimath.org). *Eventual properties related to positivity.*

This talk will survey recent results on eventual properties related to positivity (which retain some Perron-Frobenius structure), including relationships between classes of matrices such as eventually positive matrices, eventually nonnegative matrices, strongly eventually nonnegative matrices, eventually exponentially positive matrices, eventually exponentially nonnegative matrices, etc. (Received September 06, 2014)

1106-15-775 **Louis Deaett*** (louis.deaett@quinnipiac.edu) and **Gerard Lisella**. *A graph-theoretic proof of Newton's Identities.* Preliminary report.

Formulas known as "Newton's Identities" express a relationship between the elementary symmetric polynomials and the power sum symmetric polynomials. These formulas can be used, for example, to write any polynomial in one of these families in terms of polynomials in the other. These identities may also be applied to the eigenvalues of a matrix to give expressions for the coefficients of the characteristic polynomial of the matrix in terms of traces of the matrix powers. Using this fact, we exploit well-known results of combinatorial matrix theory to develop a graph-theoretic proof of Newton's Identities themselves. (Received September 06, 2014)

1106-15-806 **Catherine A. Buell*** (cbuell1@fitchburgstate.edu) and **Alex Nowak**. *Stabilizing Discrete Event Systems with Tropical Eigenvectors.* Preliminary report.

Tropical mathematics describes both the max-plus and min-plus algebras. These algebras provide a language through which we elegantly describe everyday phenomena such as the long-term behavior of discrete event systems. Extending the notion of tropical arithmetic to matrices and vectors, determining eigenvalues and associated eigenvectors, allows us to construct event systems that behave predictably and stably. First, we explore the graph theory associated with tropical eigenvalues and associated eigenspaces to address questions like shortest paths. Then, considering two classes of tropical matrices, irreducible and reducible, we look at how current algorithms compute eigenvalues of the former and conjecture necessary conditions for a stabilizing eigenvalue-vector for a reducible system. (Received September 07, 2014)

1106-15-892 **Carolyn Troha*** (carolyn.troha@uky.edu). *A Linkage Construction for Subspace Codes.*

Subspace codes were introduced in 2008 by Koetter and Kschischang. Since then there has been much research into finding constructions of good codes. Many of these known constructions rely on finding a collection of subspaces that have a nice structural property, such as having a nice underlying matrix code or having a restricted automorphism group. These codes have the disadvantage that for each new set of parameters, an entirely new code must be generated. In this talk I will present a construction, which builds a code by linking previously constructed codes. This allows for large codes without having to constuct new codes for every set of parameters. This construction also has some promise for decoding, as long as the codes being linked admit decoding algorithms. This is based on joint work with Heide Gluesing-Luerssen and Katherine Morrison. (Received September 08, 2014)

1106-15-1171 **Shaun M Fallat*** (shaun.fallat@uregina.ca), Department of Mathematics and Statistics, University of Regina, Regina, Sask, S4S 0A2, Canada, and **Mahmoud Manjegani**. *On Products and Functions of Totally Positive Matrices.* Preliminary report.

A matrix is called totally positive (resp. nonnegative) if all of its minors are positive (resp. negative). It is known that such matrices are closed under conventional multiplication, but not necessarily closed under entry-wise or Hadamard multiplication.

In this talk, we will survey some recent work on continuous entry-wise and conventional powers of totally positive matrices, in the spirit of identifying a critical exponent, should one exist. We we will consider a basic type of functions, when evaluated entry-wise preserves the property of being totally positive. (Received September 11, 2014)

1106-15-1215 **Bryant G. Mathews*** (bmathews@apu.edu). *The Tropical Orthogonal Labeling Problem.*

An orthogonal labeling of a graph is an assignment of vectors to the vertices such that the orthogonality of the vectors reflects the adjacency of the vertices. Such a labeling provides an upper bound on the minimum rank of the graph.

After showing how to define orthogonal labeling over the tropical semiring, we present results on the minimum dimension of a tropical orthogonal labeling for certain classes of graphs and compare these results to what is already known about orthogonal labelings over various fields. (Received September 11, 2014)

1106-15-1240 **Sivaram K Narayan*** (sivaram.narayan@cmich.edu), Department of Mathematics, Central Michigan University, Mount Pleasant, MI 48859. *When Leading Imply All, Mixed Matrices, and Koteljanskii Inequalities.*

An n-by-n real matrix A enjoys the *leading implies all* (LIA) property, if, whenever D is a diagonal matrix such that $A + D$ has positive leading principal minors, then all principal minors of A are positive. Symmetric and Z-matrices are known to have this property. We discuss a new class of matrices called *mixed matrices* that both unifies and generalizes these two classes and their special diagonal equivalences by also having the LIA property. *Nested implies all* (NIA) property is also enjoyed by this new class.

It is natural to ask what other properties of M-matrices and positive definite matrices are enjoyed by mixed matrices as well. We show that mixed P-matrices satisfy a broad family of determinantal inequalities, the Koteljanskii inequalities, previously known for those two classes. In the process, other properties of mixed matrices are developed, and consequences of the Koteljanskii inequalities are given.

This is a joint work with Charles R. Johnson. (Received September 11, 2014)

1106-15-1246 **Cheryl Grood**, **Johannes Harmse**, **Leslie Hogben**, **Thomas J. Hunter**, **Bonnie Jacob**, **Andrew Klimas** and **Sharon McCathern*** (smccathern@apu.edu). *The minimum rank of symmetric zero-diagonal matrices associated with a graph.*

Associated with any simple graph G is a family of symmetric matrices with the same zero-nonzero pattern as the adjacency matrix of G. The minimum rank of the matrices in this family is known as the minimum zero-diagonal rank of G and denoted $\mathrm{mr}_0(G)$.

In this talk, we characterize all connected graphs G with low ($\mathrm{mr}_0(G) \leq 3$) and high ($\mathrm{mr}_0(G) = |V(G)|$) minimum zero-diagonal ranks, and we describe the connection between the ranks of matrices associated with G and the generalized cycles that are subgraphs of G. The existence of a unique spanning generalized cycle (also known as a unique perfect $[1, 2]$-factor) of G is equivalent to $\mathrm{mr}_0(G) = |V(G)|$, and we give an algorithm for determining whether a given graph has a unique spanning generalized cycle. We also discuss the maximum zero-diagonal rank of a graph, as well as the realizable zero-diagonal ranks between minimum and maximum for a given graph. (Received September 11, 2014)

1106-15-1293 **Elise McMahon***, 948 Heartland Dr., Manteca, CA 95337. *Methods of Relating Types of Canonical Algebraic Curvature Tensors.* Preliminary report.

We relate canonical algebraic curvature tensors that are built from a self-adjoint (R^S_A) or skew adjoint (R^Λ_A) linear map A. By Nash's imbedding theorem, an algebraic curvature tensor built from a self-adjoint operator is realizable as the curvature tensor of an embedded hypersurface in Euclidean space. We develop an identity to relate the skew-adjoint canonical algebraic curvature tensor to the self-adjoint canonical tensors, which will allow us to employ previous methods to solve new problems. We compute the structure group of R^Λ_A, and develop methods for determining the linear independence of sets which contain both builds of algebraic curvature tensors. We consider cases where the operators are arranged in chain complexes and we find this case to be highly restrictive. Moreover, if one of the operators has a nontrivial kernel, we develop a method for reducing the bound on the least number of canonical algebraic curvature tensors that it takes to write an algebraic curvature tensor. (Received September 11, 2014)

1106-15-1418 **Keivan Hassani Monfared*** (k1monfared@gmail.com) and **Bryan L Shader**. *Existence of a nowhere-zero eigenbasis for a matrix whose graph and eigenvalues are prescribed.*

In this talk we use the Jacobian method to show that for any given graph G on n vertices and a set of n distinct real numbers Λ, there is a real symmetric matrix A whose graph is G and its spectrum is Λ. Then we will show that if G is connected, then A can always be chosen such that none of its eigenvalues have a zero entry. (Received September 12, 2014)

1106-15-1431 **Sewoong Oh*** (swoh@illinois.edu), 104 S. Mathews Ave, Urbana, IL 61822. *Rank Centrality: Ranking from pairwise comparisons.*

The question of aggregating pairwise comparisons to obtain a global ranking over a collection of objects has been of interest for a very long time. In most settings, in addition to obtaining a ranking, finding 'scores' for each object is of interest for understanding the intensity of the preferences. In this talk, we present Rank Centrality, an iterative rank aggregation algorithm for discovering scores for objects from pairwise comparisons. The algorithm has a natural random walk interpretation over the graph of objects with an edge present between a pair of objects if they are compared; the score, which we call Rank Centrality, of an object is assigned according to it's stationary probability under this random walk. To study the efficacy of the algorithm, we consider the popular Bradley-Terry-Luce (BTL) model. We use the comparisons theorem for comparing the stationary distribution of two random walks and the concentration inequalities for random matrices to prove an order-optimal dependence on the number of samples. (Received September 15, 2014)

1106-15-1645 **Jameson Cahill*** (jcahill@math.duke.edu) and **Dustin G Mixon**. *Robust width: A characterization of uniformly stable and robust compressed sensing.*

Compressed sensing seeks to invert an underdetermined linear system by exploiting additional knowledge of the true solution. Over the last decade, several instances of compressed sensing have been studied for various applications, and for each instance, reconstruction guarantees are available provided the sensing operator satisfies certain sufficient conditions. In this talk, we completely characterize the sensing operators which allow uniformly stable and robust reconstruction by convex optimization for many of these instances. (Received September 14, 2014)

1106-15-1663 **Wayne Barrett**, **Steve Butler** and **Minerva Catral*** (catralm@xavier.edu), 3800 Victory Parkway, Cincinnati, OH 45207, and **Shaun Fallat**, **Tracy Hall**, **Leslie Hogben**, **Pauline van den Driessche** and **Michael Young**. *Principal rank characteristic sequences.*

The principal rank characteristic sequence of an $n \times n$ matrix is a length $n+1$ sequence of 0s and 1s where, for $k = 0, 1, \dots, n$, a 1 in the kth position indicates the existence of a principal submatrix of rank k and a 0 indicates the absence of such a submatrix. We discuss results on principal rank characteristic sequences for symmetric matrices over various fields, including determining all possible such sequences over $\mathbb{R}$ up to order 7 and characterizing all possible sequences over $\mathbb{Z}_2$. (Received September 14, 2014)

1106-15-1697 **Joann Martinez Coronado*** (coronado_joann@yahoo.com). *Estimating the Dominant Eigenvector of Positive Matrices.*

Computing the eigenvectors of matrices is a useful tool in many areas of mathematics including problems involving dynamic systems. Computing eigenvectors, however, can be a slow and complicated process. For the power method, for example, given a starting vector, (such as the vector of all ones) a number of iterations must be performed before obtaining an acceptable answer for the dominant eigenvector. We would like to find a method to estimate the position of the eigenvector in a way that will decrease the number of iterations needed to reach an acceptable eigenvector. This would make the process of computing the dominant eigenvector faster and more accurate. In this study, we focus on Perron—Frobenius matrices (particularly in positive matrices) to determine what kind of relationship exists between the position of the eigenvector and the lengths of the columns of a positive matrix. We also want to explore what connection exists between the position of the eigenvector and the angles between the columns of the matrix. By creating codes in MATLAB that model these relationships, we have obtained numerical evidence that supports the existence of both of these relationships for this class of matrices. Further research will be done to quantify these relationships. (Received September 15, 2014)

1106-15-1857 **Erica Johnson*** (john1501@ravens.benedictine.edu) and **Paula Egging** (eggi1576@ravens.benedictine.edu). *Triphos: An alternative coordinate system.* Preliminary report.

In this presentation, we will explore characteristics and properties of the Triphos coordinate system, an alternative, two-dimensional coordinate plane consisting of three axes evenly spaced 120 degrees apart. The idea of this coordinate system came from students at Emporia State University. After hearing a talk on the topic from Keely Grossnickle, we were inspired to further research. We will discuss similarities and differences between the Triphos system and the traditional Cartesian coordinate system, as well as some advantages and applications of this unique coordinate system. (Received September 15, 2014)

1106-15-1881 **Patrick X. Rault*** (rault@geneseo.edu) and **Kristin A. Camenga** (kristin.camenga@houghton.edu), Houghton, NY 14744. *The numerical range of a matrix.*

Let A be an n-by-n matrix with complex coefficients. The numerical range of A, denoted $W(A)$, is the range of the map $x \mapsto \langle Ax, x\rangle$ from the unit sphere in $\mathbb{C}^n$ to $\mathbb{C}$. The set $W(A)$ is a compact, convex subset of the complex plane which contains the eigenvalues of A. We will give a classification of the shapes which $W(A)$ can take for doubly-stochastic 4-by-4 matrices A. In addition, we will apply numerical ranges to solve a question about the maximal compression of some n-by-n matrices. (Received September 15, 2014)

1106-15-1993 **Christopher J Hillar*** (chillar@berkeley.edu), Redwood Center for Theoretical Neuroscience, University of California, Berkeley, 575A Evans Hall, MC 3198, Berkeley, CA 94720, **Shaowei Lin**, Institute for Infocomm Research, Singapore, and **Andre Wibisono** (wibisono@berkeley.edu), University of California, Berkeley, EECS, Berkeley, CA 94720. *Tight bounds on the infinity norm of inverses of symmetric diagonally dominant positive matrices.*

We prove tight bounds for the infinity norm of the inverse of symmetric diagonally dominant positive matrices. Applications include numerical stability for linear systems, bounds on inverses of differentiable functions, and the consistency of maximum entropy graph distributions from single samples. Our work was inspired by sensory coding in theoretical neuroscience and we discuss some of the implications of our bounds in this setting. (Received September 15, 2014)

1106-15-2129 **Feixue Gong*** (feixue.gong@williams.edu), 2203 Paresky Center, Williamstown, MA 01267, and **Olivia Meyerson**, **Abigail Ward**, **Jeremy Meza** and **Mihai Stoiciu**. *Explicit Bounds for the Pseudospectra of Matrices and Operators.* Preliminary report.

We give several equivalent definitions for the ϵ-pseudospectrum of square matrices and investigate the behavior of the pseudospectra for non-normal matrices. We give a complete characterization of the pseudospectrum of 2×2 matrices and describe the asymptotic behavior of the pseudospectrum of a square matrix of arbitrary size, as epsilon approaches 0. We also give explicit upper and lower bounds for the ϵ-pseudospectra of bidiagonal matrices, as well as for finite rank operators. (Received September 15, 2014)

1106-15-2366 **Michael Kerckhove*** (mkerckho@richmond.edu). *Unitary Equivalence of Rank k Partial Isometries on $\mathbb{C}^n$ via the Stiefel Manifold $S(k,n)$.*

A rank k partial isometry on $\mathbb{C}^n$ factors as $A = VW^*$ for two n-by-k matrices V and W having orthonormal columns. For such matrices denote $col(V)$ by $p(V)$. The group $\mathcal{U}(n) \times \mathcal{U}(k)$ acts on matrices V, elements of $S(k,n)$, by $(U_n, U_k).V = U_n V U_k$, inducing an action of $\mathcal{U}(n)$ on $p(S(k,n))$. We show that

1) With $E = \begin{bmatrix} I_k \\ 0 \end{bmatrix}$, VW^* is unitarily equivalent to a partial isometry XE^*, and if $XE^* \sim YE^*$ then $p(Y) = h.p(X)$ for some $h \in H = \left\{ \begin{bmatrix} U_k & 0 \\ 0 & U_{n-k} \end{bmatrix} \right\}$. For $h \in H$ let $\pi(h) = U_k$.

2) With H_X the isotropy subgroup at $p(X)$, the map $\phi : H_X \to \mathcal{U}(k)$ given by $hX = X\phi(h)$ is a homomorphism and $XE^* \sim XU_k' E^*$ if and only if $U_k' = \phi(h)\pi(h)$ for some $h \in H_X$.

Together these results provide a mapping from the set of partial isometries unitarily equivalent to $A = VW^*$ into the Stiefel manifold $S(k,n)$ whose image coincides with an action of H. The orbit space for this group action then characterizes equivalence classes of rank k partial isometries on $\mathbb{C}^n$. (Received September 16, 2014)

1106-15-2393 **Dean J Katsaros*** (djkatsaros@email.wm.edu). *Decomposition of Quantum Gates.*

Unitary gate (matrix) decomposition is a fundamental research area in Quantum Information Science, being concerned with lowering the metaphoric "cost" of computation while still allowing execution of any and all operations. In particular, in the 2 qubit, or 4 by 4 unitary matrix case, we studied ways of identifying the minimum number of control gates necessary for decomposition. Furthermore, we focused on the efficiency of implementing these minimum gates, and ease of identification of decomposition method needed. Comparisons of our results with other published schemes were made and analyzed with these criteria in mind. (Received September 16, 2014)

1106-15-2577 **Diane Pelejo*** (dppelejo@email.wm.edu) and **Chi Kwong Li** (ckli@math.wm.edu). *A Decomposition Scheme for some Unitary Matrices.*

Given a 2^n-by-2^n unitary matrix U, we provide a scheme to write U as a product of matrices $U_1 \cdots U_d$ where each U_i is of the form

$$U_i = I_{2^n} + P_1^{(i)} \otimes \cdots \otimes P_n^{(i)}$$

and the P_j's are is either E_{11}, E_{22}, I_2 or $V - I_2$ for some unitary 2-by-2 matrix V. Let

$$C(U_i) = \#\{j | P_j^{(i)} = E_{11} \text{ or } E_{22}\}.$$

We say that the total cost of the decomposition is $\sum_{i=1}^{d} C(U_i)$. The scheme we present improves the cost of a previous scheme for big enough n. (Received September 16, 2014)

1106-15-2833 **Amy Streifel*** (amystreifel@gmail.com). *Skew Characteristic Polynomials of Cacti.*

In traditional adjacency matrices of graphs, if there is an edge between the ith and jth vertices of the graph, then the matrix has 1s in the (i, j) and (j, i) positions. In my research I switch things up by asking what happens if you make one of those entries a -1 instead. These are called skew-adjacency matrices. With 2^m possible skew-adjacency matrices for a graph with m edges, does this lead to an equal explosion on the number of skew characteristic polynomials? When does a graph have only one skew characteristic polynomial? Can we make graphs to get any number of possible skew characteristic polynomials we want? And how exactly does one calculate a characteristic polynomial without looking at a matrix at all? (Received September 16, 2014)

1106-15-2947 **Xin Li*** (xin.li@ucf.edu), 4000 Central Florida Blvd, Orlando, FL 32816. *A Blind Matrix Decomposition Algorithm.* Preliminary report.

Matrix decomposition is a useful tool understanding multi-dimensional data sets. For example, it can be applied to computer vision in tracking an object in video sequences or removing noise in images. We will focus on fast algorithms that can decompose a matrix into a sum of sparse, low rank, and noise components. To improve the speed of some existing algorithms, we will take advantage of recent results in random projection methods. We will illustrate our algorithm with numerical experiments in Matlab to demonstrate the improvement of the new algorithm over the existing methods. (Research based on joint work with T. Boas, K. Mercier, E. Niederman) (Received September 17, 2014)

16 ► Associative rings and algebras

1106-16-46 **David E Radford*** (radford@uic.edu), University of Illinois at Chicago, Mathematics, Statistics and Computer Science, 801 South Morgan Street, Chicago, IL 60608-7045. *Automorphisms of semisimple Hopf algebras which are biproducts.* Preliminary report.

The group of automorphisms of a semisimple Hopf algebra is well-known to be finite. We consider semisimple Hopf algebras which are biproducts and explore several notions of automorphism which take into account the additional structure of a biproduct. These notions give rise to subgroups of the full automorphism group. We examine their general structure and discuss the case when both factors of the biproduct are group algebras. These biproducts account for interesting families of semisimple Hopf algebras. (Received May 28, 2014)

1106-16-162 **Hongbo Li***, AMSS, Chinese Academy of Sciences, Zhong Guan Cun E. Rd. 55, Haidian Dist., Beijing, 100190, Peoples Rep of China, and **Lei Huang**, **Yue Liu**, **Shoubin Yao**, **Ge Li** and **Changpeng Shao**. *Syzygies for the basis-free definition of quaternionic or Clifford polynomial ring.*

A (generalized) quaternion over a field $\mathbb{K}$ of char $\neq 2$ is $\mathbf{q} = u + x\mathbf{i} + y\mathbf{j} + z\mathbf{k}$, where $u, x, y, z \in \mathbb{K}$, and $1, \mathbf{i}, \mathbf{j}, \mathbf{k}$ are the basis of quaternions. All quaternions form a non-commutative ring $\mathbb{Q}_{\mathbb{K}}$. In a quaternionic variable $\mathbf{q}$, the coefficients u, x, y, z are variables in $\mathbb{K}$. The polynomial ring $\mathbb{Q}_{\mathbb{K}}[u_\alpha, x_\alpha, y_\alpha, z_\alpha \,|\, \alpha = 1, 2, \ldots, m]$ contains a subring generated by the $\mathbf{q}_\alpha = u_\alpha + x_\alpha\mathbf{i} + y_\alpha\mathbf{j} + z_\alpha\mathbf{k}$ and the conjugate $\bar{\mathbf{q}}_\alpha = u_\alpha - x_\alpha\mathbf{i} - y_\alpha\mathbf{j} - z_\alpha\mathbf{k}$. The subring is called the quaternionic polynomial ring.

Owning to the quaternionic representation of 3-D rotations, basis-free manipulations of quaternionic polynomials has important applications in 3-D geometric deduction. In this talk we introduce our recent work on defining the basis-free quaternionic polynomial ring as the quotient of the free associative algebra generated by the $\mathbf{q}_\alpha, \bar{\mathbf{q}}_\alpha$ modulo an ideal of syzygies, the proof of the equivalence with the original definition, and the generalization to Clifford polynomial ring over 3-D inner-product space. (Received August 02, 2014)

1106-16-238 **Xingting Wang*** (xingting@uw.edu), 4131 11TH AVE NE 307, Seattle, WA 98105. *Classification of connected Hopf algebras up to prime-cube dimension.*

We classify all connected Hopf algebras up to p^3-dimension over an algebraically closed field of characteristic $p > 0$. In this talk, we are going to introduce the technique called PCD (primitive control deformation) used in the classification of p^3-dimensional connected Hopf algebras such that the primitive space of these Hopf algebras is a two-dimensional abelian restricted Lie algebra. In summary ($p > 2$), we have 2 isomorphism classes for the p-dimensional, 8 isomorphism classes for the p^2-dimensional and 55 isomorphism classes, 2 finite and 9 infinite parametric families for the p^3-dimensional. (Received August 13, 2014)

1106-16-286 **Neha Makhijani*** (nehamakhijani@gmail.com), , India, and **Rajendra K Sharma**. *The unit group of $\mathbb{F}_{q^k}(C_n \rtimes_r C_q)$.*

Let q be a prime, $\mathbb{F}_{q^k}$ be a finite field with q^k elements and $C_n \rtimes_r C_q$ be a group with presentation $\langle\ a,\ b \mid a^n,\ b^q, b^{-1}ab = a^r\ \rangle$, where $(n, rq) = 1$ and q is the multiplicative order of r modulo n. Using the theory developed by Ferraz [Simple components of the center of $FG/J(FG)$, Comm. Algebra **36**(2008) 3191–3199], we investigate the Wedderburn decomposition of the group algebra $\mathbb{F}_{q^k}(C_n \rtimes_r C_q)$ modulo its Jacobson radical. As a consequence, the structure of the unit group of $\mathbb{F}_{q^k}(C_n \rtimes_r C_q)$ is obtained when $r \not\equiv 1 \bmod d$, for any divisor d of n, $d > 1$. (Received August 19, 2014)

1106-16-517 **Kenneth L. Price*** (pricek@uwosh.edu), Department of Mathematics, University of Wisconsin Oshkosh, 800 Algoma Boulevard, Oshkosh, WI 54901. *Good Gradings of Generalized Incidence Algebras.*

This presentation relates the construction of generalized incidence algebras due to Gene Abrams and the construction of good group gradings of incidence algebras due to Molli Jones.

The speaker will provide conditions for a generalized incidence algebra to be graded isomorphic to a subring of an incidence algebra over a preorder. This allows the extension of Jones's construction to good group gradings for incidence algebras over preorders with crosscuts of length one or two. (Received September 01, 2014)

1106-16-811 **Nicholas J Werner*** (werner.79@osu.edu). *Covering Numbers of Finite Rings.*

Any finite non-cyclic group G is equal to a union of its proper subgroups. The covering number of G is the minimum number of subgroups necessary to cover G. Covering numbers are known for several classes of finite groups, and the computation of covering numbers is a problem of current interest.

In this brief talk, we will give an overview of the analogous problem for finite rings. In general, not much is known. We say that a finite (associative, unital) ring R is coverable if it is equal to a union of its proper subrings, and the covering number of R is the minimum number of subrings required to cover R. Not every finite ring is coverable, and it is nontrivial to decide whether R is coverable. We will outline the known results for coverable rings and their covering numbers, and will suggest avenues for further inquiry. (Received September 07, 2014)

1106-16-931 **Ellen E Kirkman*** (kirkman@wfu.edu), Box 7388 Reynolda Station, Wake Forest University, Winston-Salem, NC 27109, and **James J Kuzmanovich** and **James J Zhang**. *Reflection Hopf Algebras.* Preliminary report.

The Shephard-Todd-Chevalley Theorem states that when a finite group G acts linearly on a commutative polynomial ring $A = k[x_1, \ldots, x_n]$ over a field k of characteristic zero, the invariant subring A^G is a commutative polynomial ring if and only if G is generated by reflections. More generally, let H be a finite dimensional semisimple Hopf algebra that acts on an Artin-Schelter regular algebra A so that A is an H-module algebra, the grading on A is preserved, and the action of H on A is inner faithful. When A^H is Artin-Schelter regular we call H a reflection Hopf algebra for A. We present some examples of pairs (A, H), where H is a reflection Hopf algebra for A. (Received September 08, 2014)

1106-16-946 **Jonathan Axtell*** (axtell.jonathan@gmail.com), Department of Mathematics, 396 Carver Hall, Ames, IA 50011. *On Schur Superfunctors.*

We discuss super-analogues of the Schur functors defined by Akin, Buchsbaum and Weyman. Our construction realizes Schur superfunctors as objects of a category of strict polynomial superfunctors. We show that they are indecomposable objects and provide a decomposition of Schur bisuperfunctors in terms of tensor products of Schur superfunctors. These superfunctors may be viewed as characteristic-free analogues of finite-dimensional atypical irreducible modules of the Lie superalgebra $\mathfrak{gl}(m, n)$ studied by Berele and Regev. (Received September 09, 2014)

1106-16-1051 **Mitja Mastnak*** (mmastnak@cs.smu.ca). *Graded deformations of Nichols algebras.*
We study deformation of graded braided bialgebras using cohomological methods. In particular, we show that many examples of Nichols algebras are rigid. This result can be interpreted as nonexistence of braided Lie algebras with nontrivial bracket. This is joint work with I. Angiono and M. Kotchetov. (Received September 10, 2014)

1106-16-1157 **Hans-Juergen Schneider*** (hanssch@mathematik.uni-muenchen.de) and **István Heckenberger**. *The braided Hopf algebra structure of reflected Nichols algebras.*
This is joint work with István Heckenberger. The reflection operator is a basic construction in the theory of Nichols algebras of semisimple Yetter-Drinfeld modules over some Hopf algebra. We give a new and explicit description of the Hopf algebra structure of a reflected Nichols algebra based on an abstract isomorphism of braided monoidal categories. We obtain a new and direct proof of the bijection between right coideal subalgebras in a Nichols algebra and in the reflected Nichols algebra. This bijection is the main tool to prove the existence of a general PBW-decomposition of Nichols algebras extending Lusztig's PBW-basis of the plus part of quantum groups. (Received September 11, 2014)

1106-16-1195 **Sam S. Mendelson*** (smendels@gmu.edu) and **Geir Agnarsson**. *Some Special Matrix Algebra Presentations.*
A classic result in noncommutative ring theory states that a ring R is an $n \times n$ matrix ring if, and only if, R contains n^2 matrix units $\{e_{ij}\}_{1 \leq i,j \leq n}$, in which case $R \cong M_n(S)$ where S is a subring of Rn that can be described completely in terms of the matrix units. A lesser known result states that a ring R is an $(m+n) \times (m+n)$ matrix ring,so $R \cong M_{m+n}(S)$ for some ring S, if, and only if, R contains three elements a, b, and f satisfying the two relations $af^m + f^n b = 1$ and $f^{m+n} = 0$. In this talk, we investigate algebras over a commutative ring (or field) with elements c and f satisfying the two relations $c^i f^m + f^n c^j = 1$ and $f^{m+n} = 0$. Surprisingly little is known here about the structure of these algebras and about the underlying ring S for most cases of the integers i, j,m, and n. Questions whether S is non-trivial or not turn out to be surprisingly difficult to answer, let alone describing the structure of these algebras or of S in general. (Received September 11, 2014)

1106-16-1658 **W. Frank Moore*** (moorewf@wfu.edu), **Andrew Conner**, **Jason Gaddis** and **Ellen Kirkman**. *Understanding Auslander's Theorem for noncommutative algebras.* Preliminary report.
Let k be a field, let G be a finite subgroup of $\mathrm{GL}_n(k)$ whose order is invertible in k, and let G act on the polynomial algebra $S = k[x_1, \ldots, x_n]$ in the natural way. Let $R = S^G$ be the ring of invariants, and $S\#G$ denote the skew group ring.

A theorem of Auslander states that the map

$$\begin{aligned} \Phi : S\#G &\rightarrow \mathrm{End}_R(S) \\ s\#g &\mapsto (t- > sg(t)) \end{aligned}$$

is an isomorphism of graded algebras if G does not contain any nontrivial pseudo-reflections. We study the case of the skew-commutative polynomial ring $S_{-1} = k_{-1}[x_1, \ldots, x_n]$, and give evidence to support the fact that the groups to 'avoid' in this setting are different than in the commutative case. (Received September 14, 2014)

1106-16-1696 **Nicholas R. Baeth**, **Alfred Geroldinger**, **David J. Grynkiewicz** and **Daniel Smertnig*** (daniel.smertnig@uni-graz.at), Institut für Mathematik und Wiss. Rechnen, Karl-Franzens-Universität Graz, Heinrichstraße 36, 8010 Graz, Austria. *A semigroup-theoretical view of direct-sum decompositions over HNP rings.*
We study the arithmetic of direct sum decompositions of finitely generated modules over a hereditary noetherian prime ring. Let R be a (non-artinian) HNP ring, and let $\mathcal{C}$ be the class of f.g. projective right R-modules. The recent monograph by Levy and Robson describes the structure of $\mathcal{C}$ by means of simple R-modules (up to stable isomorphism of modules, and up to isomorphism if the uniform dimension of the modules is at least two). Denote by H a set of representatives of (stable) isomorphism classes of $\mathcal{C}$. Then the direct sum operation induces the structure of a commutative semigroup on H. This semigroup carries essentially all information about direct sum decompositions in $\mathcal{C}$, and hence the study of the arithmetic of direct sum decompositions in $\mathcal{C}$ can be reduced to the study of the factorization theory of the semigroup H. Using the results of Levy and Robson, we obtain a purely algebraic description of H. We investigate the half-factorial monoids obtained in this way, and are able to determine various arithmetic invariants such as the catenary and tame degree. This yields a description of the arithmetic of direct-sum decompositions in $\mathcal{C}$ in terms of the tower structure of R. (Received September 15, 2014)

1106-16-1867 **Christopher James Wilson*** (cjwilson@butler.edu), Jordan Hall 270, Butler University, 4600 W. Sunset Ave., Indianapolis, IN 46140. *Finding the hereditary crossed product that contains a given weak crossed product—when will it be weak?*

A *weak* crossed product over a discrete valuation ring is one whose cocycle is allowed to take any nonzero value (i.e. nonunit cocycle values are permitted).

Let R be a discrete valuation ring with field of fractions F, let S be the integral closure in a tamely ramified Galois extension K of F, and let $C = \sum_{\sigma \in G} Sx_\sigma$ be a weak crossed product order in the algebra $\sum_{\sigma \in G} Kx_\sigma$. We describe a process that identifies the extremal (equivalently, hereditary) crossed product order A containing C, and we give a criterion to determine whether the cocycle for A is unit-valued in S. (Received September 15, 2014)

1106-16-1871 **Maria D Vega*** (mdvega@ncsu.edu), Department of Mathematics, North Carolina State University, Raleigh, NC , and **Daniel S Sage**. *Twisted Exponents for Hopf Algebras.*

Classically, the exponent of a group is the least common multiple of the orders of its elements. This notion was generalized by Etingof and Gelaki to Hopf algebras. Kashina, Sommerhäuser and Zhu later observed that there is a strong connection between exponents and Frobenius–Schur indicators. In this talk, I will introduce a twisted version of the exponent of modules over a Hopf algebra and generalize results of Etingof and Gelaki to the twisted setting. I will also explain its relationship to twisted Frobenius–Schur indicators for semisimple Hopf algebras. In particular, I will exhibit a new formula for the twisted indicators and use it to prove periodicity and rationality statements. (Received September 15, 2014)

1106-16-1915 **Christine M Uhl*** (christineuhl@my.unt.edu). *Towards a classification of quantum Drinfeld Hecke algebras.* Preliminary report.

We give a preliminary report on a classification of quantum Drinfeld Hecke algebras in dimension 3. We will discuss the connection with rational Cherednik algebras, symplectic reflection algebras and mystic reflection groups, which play a meaningful role in noncommutative invariant theory. (Received September 15, 2014)

1106-16-1939 **David C Meyer*** (david-c-meyer@uiowa.edu). *Representations of finite subgroups of* $\mathrm{GL}_2(\mathbb{C})$ *and universal deformation rings.* Preliminary report.

Let Γ be a finite group and let V be an absolutely irreducible $\mathbb{F}_p\Gamma$-module. By Mazur, V has a universal deformation ring $R(\Gamma, V)$. This ring is characterized by the property that the isomorphism class of every lift of V over a complete local commutative Noetherian ring R with residue field $\mathbb{F}_p$ arises from a unique local ring homomorphism $\alpha : R(\Gamma, V) \to R$. Let G be a finite subgroup of $\mathrm{GL}_2(\mathbb{C})$. We associate to G a collection of finite groups $\{\Gamma\}$, where each Γ is an extension of G by an elementary abelian p-group N of rank 2, for certain choices of odd primes p. For such a group Γ, a typical absolutely irreducible $\mathbb{F}_p\Gamma$-module V will have universal deformation ring $R(\Gamma, V)$ isomorphic to the p-adic integers $\mathbb{Z}_p$. We discuss those "exceptional" V for which $R(\Gamma, V)$ is not isomorphic to $\mathbb{Z}_p$. (Received September 15, 2014)

1106-16-1948 **Dan Wackwitz*** (daniel-wackwitz@uiowa.edu). *Lifts of modules over Brauer tree algebras.* Preliminary report.

Let k be an algebraically closed field of arbitrary characteristic. Suppose A is a Brauer tree algebra over k and V is a finitely generated indecomposable A-module. I am interested in determining the versal deformation ring $R(A, V)$ of V, which is characterized by the property that every lift of V over a complete local commutative Noetherian k-algebra R with residue field k is, up to isomorphism, determined by some (not necessarily unique) local ring homomorphism from $R(A, V)$ to R. In this talk, I will discuss the special case when the Brauer tree of A is a star. In this case, every indecomposable A-module V is uniserial, and I have shown that $R(A, V)$ depends solely on the length of the composition series of V. A main ingredient in this computation is the determination of the endomorphism ring, the stable endomorphism ring and the group of self-extensions of V. (Received September 15, 2014)

1106-16-1974 **Paul Bruillard** and **Liang Chang*** (liangchang@math.tamu.edu), Department of Mathematics, Texas A&M Univeristy, College Station, TX 77843-3368, and **Cesar Galindo**, **Seung-Moon Hong**, **Ian Marshall**, **Julia Plavnik**, **Eric Rowell** and **Michael Sun**. *Representations of the loop braid group LB_3.*

The loop braid group LB_3 is defined as the motion group of 3 unknotted and unlinked oriented circles in $\mathbb{R}^3$, which is a generalization of the 3-strand braid group B_3. In this talk, we will report the recent work on the representations of LB_3 extended from the representations of B_3. (Received September 15, 2014)

1106-16-2002 **Najmeh Dehghani*** (n.dehghani@math.iut.ac.ir), Department of Mathematics, The Ohio State University-Lima, 4240 Campus Drive, Lima, OH 45804, **Fatma Azmy Ebrahim** (ebrahim.10@osu.edu), Department of Mathematics, The Ohio State University-Lima, 4240 Campus Drive, Lima, OH 45804, and **S. Tariq Rizvi** (rizvi.1@osu.edu), Deapartment of Mathematics, The Ohio State University-Lima, 4240 Campus Dr, Lima, OH 45804. *On an analogue of Schröder-Bernstein theorem.* Preliminary report.

For a ring R, we call two R-modules M and N *subisomorphic to each other* if there exist monomorphisms between each other. Analogous to Schröder-Bernstein Theorem, the question of whether two subisomorphic modules are always isomorphic, has been studied by several authors. In general the answer is in the negative. On the other hand, an affirmative answer was given for the class of (quasi-)injective modules by Bumby and for the class of continuous modules by Müller and Rizvi. It is known that one cannot weaken this beyond taking one module to be quasi-continuous while the other to be continuous. A related analogous question is that of *d-subisomorphic* modules. We say that two R-modules M and N are *direct summand subisomorphic* (or *d-subisomorphic*) if there exist R-monomorphisms $\alpha : M \rightarrowtail N$ and $\beta : N \rightarrowtail M$ such that Imα and Imβ are direct summands of N and M respectively. We study the question: when are two d-subisomorphic modules, isomorphic? We prove that if M and N are d-subisomorphic R-modules and one of them is either quasi-continuous or directly finite, then M and N are isomorphic. Related results, applications and examples will be provided. (Received September 15, 2014)

1106-16-2021 **Roberto C Soto*** (roberto-soto@uiowa.edu). *Universal Deformation Rings and Semidihedral 2-groups.* Preliminary report.

Fix an integer $n \geq 3$, and let SD denote the semidihedral group of order 2^{n+1}. Suppose k is an algebraically closed field of characteristic 2, and V is an indecomposable kSD-module. If the stable endomorphism ring of V is isomorphic to k, then it follows from work of Bleher and Chinburg that V has a universal defomation ring $R(SD, V)$. This ring is characterized by the property that every lift of V over a complete local commutative Noetherian ring R with residue field k is, up to isomorphism, determined by a unique local ring homomorphism from $R(SD, V)$ to R. In this talk we introduce endo-trivial modules and discuss the connection between endo-trivial kSD-modules and those with stable endomorphism ring isomorphic to k. (Received September 15, 2014)

1106-16-2093 **Yorck Sommerhäuser*** (yorcksom@buffalo.edu), University at Buffalo (SUNY), Department of Mathematics, 244 Mathematics Building, Buffalo, NY 14260. *A Triviality Theorem for Yetter-Drinfel'd Hopf Algebras.*

Usually, a Yetter-Drinfel'd Hopf algebra is not a Hopf algebra. Yetter-Drinfel'd Hopf algebras that are ordinary Hopf algebras are called trivial; by a result of P. Schauenburg, this happens if and only if the quasisymmetry in the category of Yetter-Drinfel'd modules accidentally coincides with the ordinary flip of tensor factors on the second tensor power of the Yetter-Drinfel'd Hopf algebra. In the case of Yetter-Drinfel'd Hopf algebras over group rings of finite groups, this happens if the degrees of homogeneous elements act trivially.

In certain situations, every Yetter-Drinfel'd Hopf algebra is trivial. One such situation will be discussed in the talk, where we will outline a proof of the following triviality theorem:

Suppose that A is a Yetter-Drinfel'd Hopf algebra over the group ring of a finite abelian group G, for a base field of characteristic zero. Suppose that A is commutative and semisimple. If the dimension of A is relatively prime to the order of G, then A is trivial.

The result was known in the case where the order of G is prime. (Received September 15, 2014)

1106-16-2329 **Jonathan S Brown***, jonathan.brown@oneonta.edu. *Primitive ideals and the variety of one-dimensional representations of finite W-algebras.* Preliminary report.

The classification of completely prime primitive ideals in the universal enveloping algebras of semisimple Lie algebras over $\mathbb{C}$ is still an open problem. One recent approach is to relate such primitive ideals to the annihilators of certain one-dimensional finite W-algebra modules via the Scryabin Equivalence. With this is mind, Premet and Topley have recently classified this variety of one-dimensional finite W-algebra modules for most of the finite W-algebras associated to classical and exceptional Lie algebras. In this talk we explain how we have extended the work of Premet and Topley to classify the variety of one-dimensional finite W-algebra modules for finite W-algebras associated to Lie algebras of sufficiently low rank. (Received September 16, 2014)

1106-16-2461 **Daniel Labardini-Fragoso*** (labardini@matem.unam.mx), Instituto de Matemáticas, Universidad Nacional Autónoma de México, Mexico. *Linear independence of generic functions in cluster algebras coming from surfaces.* Preliminary report.

This is a report on joint work with Christof Geiss and Jan Schröer.

There have been several attempts to define 'natural' bases for various classes of skew-symmetric cluster algebras. One of such attempts was made by Geiss-Leclerc-Schröer, who proposed a candidate that they called 'generic basis'. Despite its name, it has not been shown in general that the generic basis is indeed a basis of the corresponding cluster algebra. In this talk I will sketch a proof of the linear independence of Geiss-Leclerc-Schröer's 'generic basis' for (coefficient-free) cluster algebras arising from surfaces with marked points. (Received September 16, 2014)

1106-16-2636 **Feroz Siddique*** (fsiddiq2@slu.edu), Saint Louis University, Department of Mathematics and Computer Sc., 220 N Grand Blvd., St.Louis, MO 63103, India. *A generalization of Exchange rings.*

The notion of exchange property in the context of general algebra was first introduced by Crawley and Johnson [Refinements for infinite direct decompositions of algebraic systems]. Recall that a ring R is an Exchange ring, if for every right R-module A and any two decompositions A $= M \oplus N = \oplus_{i\in I} A_i$ where $M_R \cong R_R$ and the index set I is finite , there exists submodules $A_i' \subseteq A_i$ such that $A = M \bigoplus (\oplus_{i\in I} A_i')$. Nicholson [Lifting idempotents and exchange rings] calls a ring R to be clean if every element of R is the sum of an idempotent and and a unit and showed that every clean ring is an exchange ring. Camillo and Yu showed that the converse is false through an example of Bergman's. In this paper we weaken the notions of exchange(and clean) properties and draw similar relationships between them. We show that for such rings after weakening the exchange property, stable range one is equivalent to the condition that every von neumann regular element is unit regular. (Received September 16, 2014)

1106-16-2669 **Daiva Pucinskaite*** (dpucinskaite@fau.edu), Mathematical Sciences, 777 Glades Road, Boca Raton, FL 33431. *Quasi-Hereditary Structures in Representation Theory.*

Quasi-hereditary algebras appear in many areas of representation theory. For example in the theory of cluster algebras Geiss, Leclerc, Schröer study the quasi-hereditary algebras which occur as endomorphism algebras of certain maximal rigid modules over a preprojective algebra. My talk is about transfer results which utilize quasi-hereditary structures: Well known examples include the Schur-Weyl duality, which connects Schur algebras and algebras of symmetric groups, or 'Soergel Struktursatz', which shows the connection between the representation theories of Lie algebras and of associative algebras. Based on 'Soergel Struktursatz' the algebras of blocks of the Bernstein-Gelfand-Gelfand category $\mathcal{O}(\mathbf{g})$ of a simple Lie algebra $\mathbf{g}$ are related to subalgebras of the coinvariant algebra of the Weyl group of $\mathbf{g}$. I want to discuss a generalisation of 'Soergel Struktursatz' which addresses a well-known question by Humphreys on how the coinvariant algebra depends on the Bruhat order. (Received September 16, 2014)

1106-16-2887 **William Chin*** (wchin@condor.depaul.edu). *Coverings of pointed Hopf algebras.*

We discuss coverings of graded pointed Hopf algebras, which arise as coalgebra coverings of the underlying pointed coalgebras. When there are enough quadratic relations, the universal covering Hopf algebra of a bosonization of a Nichols algebra is given by the enveloping group of the underlying rack. This provides a range of finite-dimensional pointed Hopf algebras with various groups of group-like elements. We discuss some cases where Hopf algebra coverings lift to nongraded Hopf algebras. (Received September 17, 2014)

17 ▶ Nonassociative rings and algebras

1106-17-353 **Jiafeng Lv**, **Xingting Wang** and **Guangbin Zhuang***, Department of Mathematics, University of Souther California, Los Angeles, CA 90089. *Universal enveloping algebras of Poisson Hopf algebras.*

For a Poisson algebra A, by exploring its relation with Lie-Rinehart algebras, we prove a Poincaré-Birkoff-Witt theorem for its universal enveloping algebra A^e. Some general properties of the universal enveloping algebras of Poisson Hopf algebras are studied. Given a Poisson Hopf algebra B, we give the necessary and sufficient conditions for a Poisson polynomial algebra $B[x;\alpha,\delta]_p$ to be a Poisson Hopf algebra. We also prove a structure theorem for B^e when B is a pointed Poisson Hopf algebra. Namely, B^e is isomorphic to $B\#_\sigma\mathcal{H}(B)$, the crossed product of B and $\mathcal{H}(B)$, where $\mathcal{H}(B)$ is the quotient Hopf algebra B^e/B^eB^+. (Received August 24, 2014)

1106-17-619 **Seok-Jin Kang**, **Kyu-Hwan Lee*** (khlee@math.uconn.edu) and **Kyungyong Lee**. *Combinatorial approach to root multiplicities of rank two hyperbolic Kac-Moody algebras.* Preliminary report.

Root multiplicities are fundamental data in the structure of a Kac-Moody algebra. For finite and affine Kac-Moody algebras, root multiplicities are completely known. However, root multiplicities of hyperbolic Kac-Moody algebras are still mysterious. In this talk, we will consider a new combinatorial approach to root multiplicities of rank two hyperbolic Kac-Moody algebras. (Received September 03, 2014)

1106-17-692 **Pamela Estephania Harris*** (pamela.harris@usja.edu), 646 Swift Road, West Point, NY 10996, and **Erik Insko** and **Lauren Kelly Williams**. *The adjoint representation of a classical Lie algebra and the support of Kostant's weight multiplicity formula.*

Even though weight multiplicity formulas, such as Kostant's formula, exist their computational use is extremely cumbersome. In fact, even in cases when the multiplicity is well understood, the number of terms considered in Kostant's formula is factorial in the rank of the Lie algebra and the value of the partition function is unknown. In this talk, we address the difficult question: *What are the contributing terms to the multiplicity of the zero-weight in the adjoint representation of a finite-dimensional classical Lie algebra?* We describe and enumerate the cardinalities of these sets (through linear homogeneous recurrence relations with constant coefficients) for the classical Lie algebras $\mathfrak{so}_{2r+1}(\mathbb{C})$, $\mathfrak{sp}_{2r}(\mathbb{C})$, and $\mathfrak{so}_{2r}(\mathbb{C})$. (Received September 04, 2014)

1106-17-956 **Apoorva Khare*** (khare@stanford.edu). *Inclusion relations between faces of of highest weight modules.*

We report on recent progress in the study of highest weight modules $\mathbb{V}^\lambda$ over a complex semisimple Lie algebra $\mathfrak{g}$. We study the sets of weights that lie on the faces of $\mathbb{V}^\lambda$, which we call "standard parabolic subsets of weights". We show that the sets of simple roots whose corresponding standard parabolic subsets of weights are equal form intervals. Moreover, we provide the first closed-form expressions for the maximum and minimum elements of the aforementioned intervals, for all highest weight modules $\mathbb{V}^\lambda$ over semisimple Lie algebras $\mathfrak{g}$. This completely resolves questions studied by Vinberg and very recently by Cellini-Marietti; surprisingly, the max/min formulas only require the Dynkin diagram of $\mathfrak{g}$ and the integrability data of $\mathbb{V}^\lambda$.

As an application, we compute the dimension, stabilizer, vertex set, and f-polynomial of standard parabolic faces of highest weight modules, and show that they are completely determined by the aforementioned closed-form expressions. Some of these results were recently shown for the adjoint representation of a simple Lie algebra, but analogues remain unknown for any other finite- or infinite-dimensional highest weight module. (Received September 09, 2014)

1106-17-970 **Samuel Chamberlin*** (samuel.chamberlin@park.edu), 8700 NW River Park Dr. #30, Parkville, MO 64152, and **Irfan Bagci**. *Integral bases for the universal enveloping algebras of map superalgebras.*

Given a finite dimensional complex simple classical Lie superalgebra, $\mathfrak{g}$, and a complex commutative associative algebra with unity, A. We define an integral form for the universal enveloping algebra of the map superalgebra $\mathfrak{g}\otimes A$, and exhibit an explicit integral basis for this integral form. (Received September 09, 2014)

1106-17-1182 **Wayne Johnson*** (waj@uwm.edu). *A multivariate generating function for the Weyl Dimension Formula.*

We present a closed form for a multivariate generating function for the dimensions of the irreducible representations of a semisimple, simply connected linear algebraic group over $\mathbb{C}$ whose highest weights lie in a finitely generated lattice cone in the dominant chamber. This result generalizes the formula for the Hilbert series of an equivariant embedding of a homogeneous projective variety. We use the result to compute multivariate Hilbert series for some interesting examples. (Received September 11, 2014)

1106-17-1495 **Brad J Schleben*** (schleben@uwm.edu). *An infinite wedge representation of the Lie superalgebra $\mathfrak{gl}_{\infty|\infty}$.*

In this talk, we look at an infinite wedge representation of the Lie superalgebra $\mathfrak{gl}_{\infty|\infty}$. This serves as an analogue to Victor Kac's construction of the basic representation of the Lie algebra $\mathfrak{gl}_\infty$, which is of fundamental importance for mathematical physics in the context of the boson-fermion correspondence. (Received September 13, 2014)

1106-17-1522 **Nicole Kroeger*** (nkroeger@alumni.nd.edu), 401 Railroad Ave, Hartsville, SC 29550. *Coisotropic subalgebras of complex semisimple Lie bialgebras.*

In his paper "A Construction for Coisotropic Subalgebras of Lie Bialgebras," Marco Zambon gave a way to use a long root of a complex semisimple Lie bialgebra $\mathfrak{g}$ to construct a coisotropic subalgebra of $\mathfrak{g}$. In this paper, we genearlize Zambon's construction. Our construction is based on the theory of Lagrangian subalgebras of the double $\mathfrak{g} \oplus \mathfrak{g}$ of $\mathfrak{g}$, and our coisotropic subalgebras correspond to torus fixed points in the variety $\mathcal{L}(\mathfrak{g} \oplus \mathfrak{g})$ of Lagrangian subalgebras of $\mathfrak{g} \oplus \mathfrak{g}$. (Received September 13, 2014)

1106-17-2166 **Lindsey Bosko-Dunbar** and **Matthew Burke*** (mjburke@email.shc.edu), Tyler, TX 75701, and **Jonathan Dunbar**, **J.T. Hird** and **Kristen Stagg-Rovira**. *Solvable Leibniz Algebras with Abelian Nilradical.*

We extend the classification of solvable Lie algebras with Abelian nilradical to classify solvable Leibniz algebras which are one dimensional extensions of an Abelian nilradical. (Received September 15, 2014)

1106-17-2305 **Joseph B Timmer*** (jtimme1@lsu.edu), 333 Lockett Hall, Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803-4918. *Bismash Products and Exact Factorizations of S_n.*

With an exact factorization of a finite group $L = FG$, one may construct the bismash product Hopf algebra $H = k^G \# kF$. If one were to factor the symmetric group $S_n = FG$, the resulting Hopf algebras have some interesting properties; mostly concerning the indicator values of irreducible modules. In this talk, we present some new results concerning bismash products in general and for those that arise from exact factorizations of S_n. (Received September 16, 2014)

1106-17-2361 **Yevgenia Kashina*** (ykashina@depaul.edu), Department of Mathematical Sciences, DePaul University, Chicago, IL 60614. *On classification of semisimple Hopf algebras.*

In this talk we will discuss classification of semisimple Hopf algebras of dimension 32 with a commutative Hopf subalgebra K of dimension 16 over an algebraically closed field k of characteristic 0. We will concentrate on the case when K is not cocommutative, that is, K is isomorphic to k^G for some nonabelian group G of order 16. There are exactly nine nonisomorphic nonabelian groups of order 16. For some of the cases we will be able to show that, together with K, the Hopf algebra contains another Hopf subalgebra of dimesion 16, which is both commutative and cocommutative. (Received September 16, 2014)

1106-17-2500 **Rebecca L. Jayne*** (rjayne@hsc.edu), Box 187, Hampden-Sydney, VA 23943. *A count of maximal dominant weights of integrable modules.*

Let $V(k\Lambda_0)$ be the integrable highest weight $\widehat{sl}(n)$-module. A dominant weight $V(k\Lambda_0)$ is maximal when $\mu+\delta$ is not a weight. We explicitly describe the maximal dominant weights of $V(k\Lambda_0)$ and conjecture that the number of these weights is given by the number of necklaces with n beads, k of which are white and $n-k$ of which are black. In particular, we prove that the counts match when $k = 2, 3$. This is a joint work with Kailash Misra. (Received September 16, 2014)

18 ► Category theory; homological algebra

1106-18-224 **Eric C Rowell*** (rowell@math.tamu.edu), Math. Dept. MS 3368, Texas A&M University, College Station, TX 77843. *Classification of Modular Categories.*

I will report on the ongoing classification project for modular categories. This is joint work with several coauthors, including Zhenghan Wang, Richard Ng, Cesar Galindo, Paul Bruillard and Julia Plavnik. I will mainly focus on classification by rank (the number of simple objects), with an emphasis on weakly integral modular categories. (Received August 12, 2014)

1106-18-598 **Paul Bruillard**, **César Galindo**, **Seung-Moon Hong**, **Yevgenia Kashina**, **Deepak Naidu*** (dnaidu@math.niu.edu), **Sonia Natale**, **Julia Yael Plavnik** and **Eric C. Rowell**. *Classification of integral modular categories of Frobenius-Perron dimension pq^4 and p^2q^2.*

In my talk, I will discuss the classification of integral modular categories of dimension pq^4 and p^2q^2, where p and q are distinct primes. I will explain why such categories, except for those of dimension $4q^2$, are always group-theoretical. I will identify the non-group-theoretical integral modular categories of dimension $4q^2$ as certain categories arising from Tambara-Yamagami categories and quantum groups. (Received September 03, 2014)

1106-18-1075 **Brian J. Paljug*** (brian.paljug@temple.edu) and **Vasily A. Dolgushev** (vasily.dolgushev@temple.edu). *The Grothendieck-Teichmuller group, homotopy algebras, and formality morphisms.*

The Grothendieck-Teichmuller group GRT is a mysterious mathematical object with deep and surprising connections to mathematical physics, number theory, deformation quantization, and more. GRT acts simply transitively on the set of homotopy classes of formality morphisms, L_∞ morphisms that are the key ingredient in Kontsevich's deformation quantization of Poisson manifolds. In fact, GRT may act on formality morphisms in several ways, and so it is natural to ask if these actions coincide. After defining GRT using the operad of parenthesized braids and reviewing formality morphisms, we will discuss the various ways that GRT acts on these morphisms, and give an idea of why these actions agree. This is joint work with Vasily Dolgushev. (Received September 10, 2014)

1106-18-1297 **Inna I Zakharevich*** (zakh@math.uchicago.edu). *An investigation of small model categories.*

Model categories have been widely used since their introduction by Quillen in 1967, and although many techniques exist for constructing model categories the most fundamental question remains open: given a bicomplete category $\mathcal{C}$ together with a subcategory $\mathcal{W}$, when does there exist a model structure on $\mathcal{C}$ with $\mathcal{W}$ as the subcategory of weak equivalences? This question is fundamentally important, as model categories do not generally arise naturally "in the wild"; instead, one generally has a category with a subcategory of weak equivalences, and must construct the model structure by hand. Although this question is very difficult in general, it turns out that when $\mathcal{C}[\mathcal{W}^{-1}]$ is a preorder the question can often be answered. We present some techniques for dealing with this question in general and, in the case when $\mathcal{C}$ is small, give necessary and sufficient conditions for the existence of a model structure. (Received September 11, 2014)

1106-18-1699 **Martina Rovelli***, martina.rovelli@epfl.ch. *A looping-delooping adjunction for topological spaces.*

Farjoun and Hess introduced twisted homotopical categories, a framework for monoidal categories that come with a looping-delooping adjunction between monoids and comonoids, in which a formal theory of bundles is available. Although much of this kind of structure was inspired by classical constructions and results holding for topological spaces, it does not not seem possible to construct a full twisted homotopical structure for spaces. However, we provide a *weak twisted homotopical structure*, by showing that (Milnor's model of) the loop space functor and the classifying space functor form a sort of adjunction between pointed spaces and topological groups. The argument leads to a classification of principal bundles over a fixed space that is dual to the well-known classification of bundles with a fixed group. As a consequence, it is also possible to extend Milnor's loop space construction to a pseudofunctorial assignment. (Received September 15, 2014)

1106-18-1769 **Peter Schauenburg*** (peter.schauenburg@u-bourgogne.fr), Institut de Mathématiques de Bourgogne, UMR 5584 du CNRS, 9 avenue Alain Savary, BP 47870, 21078 Dijon, France. *Higher Frobenius-Schur Indicators for Group-Theoretical Categories.* Preliminary report.

Higher Frobenius-Schur indicators are invariants of (objects in) pivotal fusion categories. We report on the explicit calculation of these indicators for specific examples, namely for group-theoretical categories, which are associated to inclusions of finite groups, possibly with cohomological data. (Received September 15, 2014)

1106-18-2068 **Paul Bruillard**, **César Galindo**, **Seung-Moon Hong**, **Julia Yael Plavnik*** (plavnik@famaf.unc.edu.ar), **Eric C. Rowell** and **Michael Sun**. *On strictly weakly integral modular categories of rank 8 and 9.* Preliminary report.

Modular categories are algebraic objects that appear in several mathematical areas, such as topological quantum field theories, conformal field theory, quantum groups, subfactor theory, quantum computing and others. A modular category is a non-degenerated ribbon fusion category over the complex numbers. Fusion categories are rigid semisimple tensor categories with only finite isomorphism classes of simple objects. The number of ismorphism classes of simple objects is called the rank of the fusion category.

In this talk, we will discuss some approaches to classifying modular categories by rank and we will recall some of the known results. We will also present some results of our current work and some ideas of the proofs. The main theorem is the following.

Theorem: There are no strictly weakly integral modular categories of rank 8.

At the moment, we have the conjecture that strictly weakly integral modular categories of rank 9 are Grothendieck equivalent, which means that they have the same fusion rules, to $\mathrm{Ising} \boxtimes \mathrm{Ising}$, $\mathrm{Ising} \boxtimes \mathrm{Rep}(\mathbb{Z}/2\mathbb{Z})$

or SO(11)_2. We have achieved some positive results and there is only one remaining case. (Received September 15, 2014)

1106-18-2090 **Xiao-Gang Wen*** (wen@dao.mit.edu), 6c-317, Dept. of Physics, Massachusetts Institute of Technology, 77 Massachusetts Ave., Cambridge, MA 02139. *Patterns of many-body entanglement and tensor category theory.*

Many-body entanglement (i.e. quantum phases of matter with topological order) is a truly new phenomenon. A new phenomenon in physics usually requires new mathematics to describe it. The continuous mechanical motion studied by Newton requires calculus. The general relativity of Einstein requires Riemannian geometry. Quantum phenomena require linear algebra. Right now, we are facing a similar situation: many-body entanglement and new topological phases of matter requires new mathematics, such as tensor category theory, to describe it. In this talk, I will explain how tensor category theory, group cohomolgy, etc may become the mathematical foundation for many-body entanglement and new topological phases of matter. The topological degeneracy in topological phases of matter can be used as qubits that naturally resists decoherence. So topological matter is a natural medium (and the only medium) to perform fault tolerant quantum computation. This becomes the field of topological quantum computation. (Received September 15, 2014)

1106-18-2111 **Ryan Johnson**, **Siu Hung Ng**, **David Penneys**, **Jolie Roat*** (jdroat@iastate.edu), **Matthew Titsworth** and **Henry Tucker**. *On the classification of rank 4 fusion categories.* Preliminary report.

The classification of rank 2 fusion categories was completed by Victor Ostrik in 2003. Recently, some advancement of the subject area led to the classification of rank 3 fusion categories with pivotal structure, again by Ostrik, in 2013. In 2014, Hannah Larson continued with the classification of pseudo-unitary fusion categories containing non-self-dual simple objects using newly developed number theory results. In this talk we will report some progress on the classification of rank 4 pseudo-unitary fusion categories with only self-dual simple objects. (Received September 15, 2014)

1106-18-2331 **Denise A. Rangel Tracy*** (detracy@syr.edu). *On Modules with an Upper Triangular Presentation Matrix.*

In this talk we will investigate presentation matrices of totally reflexive modules over commutative local rings with the cube of the maximal ideal equaling zero. Totally reflexive modules give rise to complete resolutions, a "doubly " infinite exact complex of finitely generated free modules. We will give a necessary and sufficient condition for when each differential in such a complex can be simultaneously represented by an upper triangular matrix. (Received September 16, 2014)

1106-18-2364 **Maissam Barkeshli*** (mbarkeshli@gmail.com), Microsoft Station Q, Santa Barbara, CA, **Parsa Bonderson**, Microsoft Station Q, Santa Barbara, CA, **Meng Cheng**, Microsoft Station Q, Santa Barbara, CA , and **Zhenghan Wang**, Microsoft Station Q, Santa Barbara, CA. *Symmetry, Defects, and Gauging of Topological Phases.*

The mathematical description of topological states of matter in two spatial dimensions is the theory of unitary braided tensor categories (UBTC). Here we examine the interplay of symmetry and topological order, developing a classification of symmetry-enriched topological phases with unitary symmetry G, for a topological phase described by a UBTC $\mathcal{C}$. Extrinsic defects associated with $g \in G$ exhibit a rich set of properties. We develop a general formalism, based on module categories, known as a G-crossed braided tensor category, to characterize the properties of such defects. We derive a set of data and consistency conditions, solutions of which define the defect theory $\mathcal{C}_G^\times$, which is referred to as a G-crossed extension of $\mathcal{C}$. This allows us to systematically compute many properties of the defects. We introduce the notion of G-crossed modular transformations for $\mathcal{C}_G^\times$, and derive a generalized Verlinde formula. We conjecture that distinct $\mathcal{C}_G^\times$ fully characterize all possible G-symmetric topological phases. Promoting G to a gauge symmetry deconfines the extrinsic G-defects and results in a different topological order $\mathcal{C}/G$. (Received September 16, 2014)

1106-18-2368 **E. Ardonne**, **P. Finch** and **M. Titsworth*** (matthew.titsworth@utdallas.edu), 800 W Campbell Dr, Richardson, TX 75080. *On the classification of fusion categories Grothendieck equivalent to $B_{p,2}$.* Preliminary report.

In this talk we report on a family fusion categories associated to the B-series affine Lie algebras at level 2. We give an explicit presentation of their arithmetic data, discuss the structure of their monoidal equivalences and present progress towards showing that this is all of the monoidal equivalence classes. (Received September 16, 2014)

1106-18-2465 **Ryan Timothy Johnson*** (johnsor@grace.edu), Grace College, 200 Seminary Drive, Winona Lake, IN 46590. *An invariant that distinguishes Tambara-Yamagami categories.*

In this talk, we investigate the higher Frobenius-Schur indicator introduced by Ng and Schauenburg and prove that it is a strong enough invariant to distinguish between any two Tambara-Yamagami fusion categories. Our method of proof is based on computation of the Frobenius-Schur indicators as Gauss sums for certain quadratic forms on finite abelian groups and relies on the classification of quadratic forms on finite abelian groups due to Wall.

As a corollary to our work, we show that the state-sum invariants of 3-manifolds associated with Tambara-Yamagami categories determine the category as long as we restrict to Tambara-Yamagami categories coming from groups G whose order is not a power of 2. Turaev and Vainerman proved this result under the assumption that G has odd order and they conjectured that a similar result should hold for Tambara-Yamagami categories coming from even-order groups. Their proof used the state-sum invariant of lens spaces $L_{k,1}$. We provide an example showing that the state-sum invariants of lens spaces is not enough to distinguish all Tambara-Yamagami categories. (Received September 16, 2014)

1106-18-2477 **Derek K Wise*** (derek.wise@fau.de), Department Mathematik, FAU Erlangen-Nürnberg, Cauerstr. 11, 91058 Erlangen, Germany. *Hopf algebra gauge theory.* Preliminary report.

An elegant approach to gauge theory uses the groupoid of connections and gauge transformations. A natural question is what happens to this groupoid when the gauge group is replaced by a Hopf algebra. I will explain recent joint work with Catherine Meusburger on Hopf algebra gauge theory and in particular how the connection groupoid becomes a Hopf algebroid. I will also discuss the relevance to contemporary models from physics. (Received September 16, 2014)

1106-18-2836 **Adnan Abdulwahid** and **Miodrag Iovanov*** (miodrag-iovanov@uiowa.edu). *Cofree coalgebras in common abelian monoidal categories.* Preliminary report.

The tensor algebra is a well known construction which carries over to (symmetric) abelian monoidal categories, and produces the free algebra (monoid) on an object V in the category. The existence of a free algebra in the opposite category of an abelian monoidal category C, or the co-free coalgebra on an object V in C is less obvious; the existence of a cofree coring (cofree coalgebra in the category of bimodules over a ring) was left open in [A.Agore, Proc.AMS 139 (2011), 855-863]. Using the special adjoint functor theorem, we show that for many abelian monoidal categories of interest (bimodules, (co)modules over bialgebras B, Yetter-Drinfeld modules, etc.), the answer to this question is positive. In particular, the cofree (co)module coalgebra on a B-(co)module exists. We also determine generators of the category of coalgebras in each of these monoidal categories and give an explicit construction of the cofree coalgebra in each case. We investigate whether such a general construction works for general monoidal categories satisfying certain natural conditions that are met in all the above cases. (Received September 16, 2014)

19 ► K-theory

1106-19-535 **Paul Frank Baum*** (baum@math.psu.edu), Department of Mathermatics, Penn State University, University Park, PA 16802. *Expanders — Exact and Morita-compatible crossed products.*

An expander or expander family is a sequence of finite graphs $X_1, X_2, X_3, ...$ which is efficiently connected. A discrete group G which contains an expander in its Cayley graph is a counter-example to the Baum-Connes (BC) conjecture with coefficients. M. Gromov outlined a method for constructing such a group. G. Arjantseva and T. Delzant completed the construction. Any group so obtained is known as a Gromov group or Gromov monster group, and these are the only known examples of a non-exact groups.

The left side of BC with coefficients "sees" any group as if the group were exact. This talk will indicate how to make a change in the right side of BC with coefficients so that the right side also "sees" any group as if the group were exact. This corrected form of BC with coefficients uses the unique minimal exact and Morita-compatible intermediate crossed-product. For exact groups, there is no change in BC with coefficients.

In the corrected form of BC with coefficients a Gromov group acting on the coefficient algebra obtained from an expander is not a counter-example. Thus at the present time (September, 2014) there is no known counter-example to the corrected form of BC with coefficients. The above is joint work with E. Guentner and R. Willett. (Received September 01, 2014)

1106-19-1682 **Vincent F Longo*** (longov1@tcnj.edu), 357 Harford Rd, Somerdale, NJ 08083. *Knot Invariants from Spanning Surfaces for a Two-Bridge Knot.*

The Alexander polynomial of a knot is one of the most well known and useful knot invariants in the field of Knot Theory. One way of finding the Alexander polynomial of a knot is by constructing a matrix using the unique orientable surface bounded by the knot, and taking the determinant of that matrix. We present an extension of this notion for non-orientable surfaces bounded by a knot by defining the State polynomials of a two-bridge knot. We then present some of the properties shared by the State polynomial and Alexander polynomial, along with some notable differences between the two.
(Received September 15, 2014)

20 ► Group theory and generalizations

1106-20-47 **Joseph Kirtland*** (joe.kirtland@marist.edu), Department of Mathematics, Marist College, Poughkeepsie, NY 12601. *Finite Inseparable p-Groups.* Preliminary report.

A finite group is *inseparable* if does not split over any proper nontrivial normal subgroup; that is, if it has no nontrivial semidirect product decompositions. This talk investigates finite inseparable p-groups and, under certain conditions, establishes a necessary and sufficient condition for inseparability. (Received May 28, 2014)

1106-20-73 **Primoz Moravec*** (primoz.moravec@fmf.uni-lj.si), Fakulteta za matematiko in fiziko, 1000 Ljubljana, Slovenia. *Bogomolov multipliers of groups.*

The Bogomolov multiplier is a group theoretical invariant isomorphic to the unramified Brauer group of a given quotient space, and represents an obstruction to Noether's problem on rationality of fixed fields. In this talk we survey some recent results regarding Bogomolov multipliers. We describe a homological version of the Bogomolov multiplier, which relies on universality of certain commutator relations in groups. We exhibit a Hopf-type formula, find a five term exact sequence corresponding to this invariant, and describe the role of the Bogomolov multiplier in the theory of central extensions. An algorithm for computing the Bogomolov multiplier is outlined. (Received June 28, 2014)

1106-20-123 **Peter Loth*** (lothp@sacredheart.edu), Department of Mathematics, Sacred Heart University, Fairfield, CT 06825. *Partial decomposition bases and partial subbases.* Preliminary report.

Warfield groups are direct summands of simply presented abelian groups or, alternatively, are abelian groups G possessing a nice decomposition basis X such that $G/\langle X\rangle$ is simply presented. The concept of decomposition basis was generalized to the notion of partial decomposition basis by Jacoby in order to extend Barwise and Eklof's classification of torsion groups in $L_{\infty\omega}$ to Warfield groups. In this talk, we explore some algebraic characteristics of the class of groups with partial decomposition bases. We prove a characterization of subgroups possessing a partial subbasis and discuss applications. (Received July 23, 2014)

1106-20-289 **Elizabeth Leyton Chisholm*** (eeleyton@math.ucsb.edu) and **Jon McCammond**. *Braid groups and euclidean simplices.*

When Krammer and Bigelow independently proved that braid groups are linear, they used the Lawrence-Krammer-Bigelow representation for generic values of its variables q and t. The t variable is closely connected to the traditional Garside structure of the braid groups and it plays a major role in Krammer's proof. The q variable, associated with the dual Garside structure of the braid groups, has received less attention.

In the special case $t = 1$ and q real, we show that there is an elegant geometric interpretation of the LKB representation that highlights the role of the q variable, at least when it is viewed in Krammer's original basis. Concretely, braid group elements can be viewed as acting on and systematically reshaping euclidean simplices. In fact, for each simple element in the dual Garside structure, the reshaping is an elementary operation that we call edge rescaling. (Received August 19, 2014)

1106-20-318 **Rostislav I Grigorchuk*** (grigorch@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77843, and **Dmytro M Savchuk** (savchuk@usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 E Fowler Ave, CMC342, Tampa, FL 33620. *Ergodic decomposition of group actions on rooted trees.*

First, we prove a general result about the decomposition on ergodic components for group actions on boundaries of spherically homogeneous rooted trees. Namely, we identify the space of ergodic components with the boundary of the orbit tree associated with the action, and show that the canonical system of ergodic invariant probability measures coincides with the system of uniform measures on the boundaries of minimal invariant subtrees of the tree.

A special attention is given to the case of groups generated by finite automata. Few examples, including the lamplighter group, Sushchansky group, and the, so called, Universal group are considered in order to demonstrate possible applications of the theorem. (Received August 21, 2014)

1106-20-333 **Mark L. Lewis*** (lewis@math.kent.edu), Department of Mathematical Sciences, Kent State University, Kent, OH 44242. *Recent work and current problems in character degrees.*

For a finite group G, we let $\mathrm{Irr}(G)$ denoted the set of irreducible characters of G. The set of character degrees of G is the set $\mathrm{cd}(G) = \{\chi(1) \mid \chi \in \mathrm{Irr}(G)\}$. We will survey a number of recent results regarding $\mathrm{cd}(G)$. This will include results regarding graphs associated with character degrees. As we go along, we will highlight a number of open problems, and we will discuss how one might approach some of these open problems. (Received August 22, 2014)

1106-20-334 **Anisah Nu'Man*** (s-anuman1@math.unl.edu), Department of Mathematics, 203 Avery Hall, PO Box 880130, Lincoln, NE 68588-0130. *Tame filling invariants, examples, and closure properties.* Preliminary report.

Filling invariants are quasi-isometry invariants for groups with finite presentations defined using properties of van Kampen diagrams. Intrinsic and extrinsic tame filling functions are a recent pair of asymptotic invariants that are a strengthening of the intrinsic diameter (i.e., isodiametric) function and the extrinsic diameter function. Mihalik and Tschantz defined the related concept of tame comb able groups, and Brittenham and Hermiller showed that the existence of a (finite-valued) tame filling function implies that the group is tame combable. Here we give examples of tame filling functions and how they behave under group constructions. (Received August 22, 2014)

1106-20-365 **Ellen Ziliak*** (eziliak@ben.edu), **Catherine Buell** (catherine.a.buell@gmail.com), **Loek Helminck** (loek@ncsu.edu), **Vicky Kilma** (klimavw@gmail.com), **Jennifer Schaefer** (schaefje@dickinson.edu) and **Carmen Wright** (carmen.m.wright@jsums.edu). *Symmetric Spaces for $SL_n(\mathbb{F}_q)$ and Finitely Presented Groups.* Preliminary report.

Symmetric spaces were introduced by Élie Cartan as a special class of homogeneous Riemannian manifolds. These spaces have since been generalized and a rich theory has been developed that plays a role in many fields of research. In this talk we will focus on generalized symmetric spaces which can be defined as the homogeneous spaces G/H with G an arbitrary group and H the fixed point group of an involution. The map $\tau : G \to G$ defined by $\tau(g) = g\theta(g)^{-1}$ where θ is the involution induces an isomorphism of the coset space G/H onto the image $\tau(G) = Q$. In addition we can consider the extended symmetric space $R = \{g \in G|\theta(g) = g^{-1}\}$. In general $Q \subseteq R$ but typically $Q \neq R$. However in this talk it will be shown that for $G = SL_n(\mathbb{F}_q)$, if θ is an outer automorphism it is the case that $R = Q$ however when θ is an inner automorphism the theorem is not always true. A similar analysis can be done for finitely presented groups, I will end by explaining this process. (Received September 09, 2014)

1106-20-388 **Paul E. Becker*** (peb8@psu.edu), **Jennifer Ulrich**, **Sheridan Houghten** and **Martin Derka**. *A natural two-generator construction of the sporadic Mathieu group M_{24}.*

The sporadic group M_{24} is known to be the full automorphism group of the extended binary Golay code. We discuss two very simple constructions for the Golay code; each admits a natural automorphism. We then correlate the two constructions, producing two permutations which are sufficient to generate M_{24}. (Received August 26, 2014)

1106-20-442 **Robert Fitzgerald Morse*** (morse@evansville.edu). *Capable special p-groups of rank 2: The isomorphism problem.*

A finite p-group G such that $G' = Z(G)$ and G' is an elementary abelian p-group of rank 2 is called special of rank 2. A group G is capable if there exists a group H such that $H/Z(H)$ is isomorphic to G. A result of H. Heineken shows the capable special p-groups of rank 2 have order at most p^7. Of such groups of exponent p we know from published classifications that there is a constant number of isomorphism classes. The number of isomorphism classes of special p-groups of rank 2 and exponent p^2 grows with p for groups of order p^5, p^6, and p^7. However, our use of the small groups library in GAP gives evidence that the number of capable special groups of each order is constant. Hence, the capable special p-groups of rank 2 and exponent p^2 cannot only be characterized by a structure description but can actually be classified. We will show that for odd p there are three isomorphism classes each for capable special p-groups of rank 2 exponent p^2 and order p^5 and p^6 and one such class for order p^7.

This is joint work with Hermann Heineken and Luise-Charlotte Kappe. (Received August 28, 2014)

1106-20-444 **Luise-Charlotte Kappe*** (menger@math.binghamton.edu). *Capable special p-groups of rank 2: Structure results.*

A finite p-group G such that $G' = Z(G)$ and G' is an elementary abelian p-group of rank 2 is called special of rank 2. A group G is capable if there exists a group H such that $H/Z(H)$ is isomorphic to G. The goal of this research is to classify up to isomorphism all of the capable special p-groups of rank 2. In this talk we will determine the structure of these groups, give a parameterized presentation for each group and provide a criterion for exactly when a special p-group of rank 2 and exponent p^2 is capable.

This is joint work with Hermann Heineken and Robert F. Morse. (Received August 28, 2014)

1106-20-473 **Marianna C. Bonanome***, 300 Jay Street, Brooklyn, NY 11201, and **Margaret H. Dean**. *Some important properties of Grigorchuk's group.* Preliminary report.

In 1980 R. Grigorchuk introduced a group which is now known as "Grigorchuk's group." It is an important object in the field of geometric group theory, particularly in the study of branch groups and self-similar groups. Its properties have helped resolve several long-standing open problems. In 1984, Grigorchuk proved that his group is an example of a group with "growth" that is intermediate, faster than polynomial but slower than exponential, thus providing an answer to an open question posed by John Milnor in 1968. Grigorchuk's group is also the first example of a finitely generated group that is amenable but not elementary amenable, providing an answer to another long-standing problem posed by Mahlon Day. In our talk we give a brief history of this famous group, introduce some if its fascinating properties and discuss recent research. (Received August 29, 2014)

1106-20-474 **Margaret H. Dean*** (mdean@bmcc.cuny.edu), mdean@bmcc.cuny.edu, and **Marianna C. Bonanome**. *Dead-end elements and dead-end depth in groups.* Preliminary report.

The idea of a *dead-end* element in a group G was first introduced by O.V. Bogopolski in 1997. If G has a finite generating set X, an element g is a dead-end element if $|gx| \leq |g|$, for all $x \in X^{\pm}$. The *dead-end depth* of G is the minimal integer N such that given any group element g, there is a path in the Cayley graph for G leading from g to a point farther from the identity than g, whose length is no more than N. The dead-end depth of a group depends on the generating set X. We will give an introductory overview of dead-end elements and dead-end depth, and discuss some of the recent research pertaining to Thompson's group F and the Lamplighter Group, as well as other groups. (Received September 16, 2014)

1106-20-523 **David Plaxco*** (dplaxco@vt.edu), 460 McBryde Hall, Virginia Tech, 225 Stanger Street, Blacksburg, VA 24061. *Reverse Cayley Graphs: Imposing Group Structure on the Platonic Solids.*

The algorithm for generating a Cayley graph for a given group presentation is relatively straightforward. However, there are no general techniques for carrying out the reverse process: determining which group presentations might generate a given graph. Some characteristics of the graph, such as regularity or connectivity, might provide relatively straightforward insight into whether a graph could even be considered a Cayley graph. Skeletons of the five classical Platonic solids provide good initial candidates for the reverse Cayley graph problem based on their regularity, planarity, and finiteness. In this presentation, I discuss ad hoc approaches to determining which group presentations generate Platonic solid skeletons as Cayley graphs. I then discuss an exhaustion of the problem using all presentations of groups of order 4, 6, 8, 12, and 20. (Received September 01, 2014)

1106-20-530 **Russell D Blyth*** (blythrd@slu.edu), **Francesco Fumagalli** (fumagalli@math.unifi.it) and **Marta Morigi** (marta.morigi@unibo.it). *The solvability of groups with nilpotent minimal coverings.*

A *covering* of a group is a finite set of proper subgroups whose union is the whole group. A covering is *minimal* if there is no covering of smaller cardinality, and it is *nilpotent* if all its members are nilpotent subgroups. We complete a proof that every group that has a nilpotent minimal covering is solvable, starting from the previously known result that a minimal counterexample is an almost simple finite group. (Received September 01, 2014)

1106-20-531 **Joseph Phillip Brennan*** (jbrennan@binghamton.edu), Binghamton, NY , and **Luise-Charlotte Kappe**. *Variation on a Theme of I.D. MacDonald.*

In a 1963 paper I.D. MacDonald gave an example of a group in which the cyclic commutator subgroup is not generated by a commutator and he gives sufficient conditions on the group G such that its cyclic commutator subgroup is generated by a commutator. The question arises, what is the situation for other words in case the associated word subgroup is cyclic, in particular the word x^n, n a positive integer.

For n a positive integer, we establish sufficient conditions such that $G^n = \langle g^n \mid g \in G \rangle$ is generated by an n-th power in case G^n is cyclic and give examples of groups G, where G^n is cyclic but not generated by the n-th power of an element. Further, we show that if G^n is cyclic, there exists elements $g, h \in G$ such that $G^n = \langle g^n, h^n \rangle$. (Received September 01, 2014)

1106-20-560 **Benjamin Steinberg*** (bsteinberg@ccny.cuny.edu) and **Mike Boyle**, Department of Mathematics, University of Maryland, College Park, MD 20742-4015. *The decidability of flow equivalence for shifts of finite type and stable isomorphism for Cuntz Krieger C^*-algebras.*

One of the oldest open questions in symbolic dynamics is to decide whether two shifts of finite type are conjugate. Flow equivalence, an important coarsening of conjugacy, has also been highly studied. We show, based on work of Boyle and Huang, that flow equivalence is decidable for shifts of finite type. We also provide a decision procedure for the closely related problem of whether the Cuntz-Krieger algebras associated to shifts of finite type are stably isomorphic.

The decision procedures are based on deep decidability results in geometric group theory. (Received September 08, 2014)

1106-20-569 **Christopher O'Neill** and **Vadim Ponomarenko*** (vponomarenko@mail.sdsu.edu), Department of Mathematics and Statistics, San Diego State University, 5500 Campanile Dr., San Diego, CA 91941-7720, and **Claire Spychalla**. *Arithmetic of Numerical Semigroups on Compound Sequences.*

An increasing sequence $A = (a_1, a_2, \ldots, a_n)$ of natural numbers is called *compound* if it satisfies the condition $a_2 a_3 \cdots a_{n-1} \leq \gcd(a_1, a_2)\gcd(a_2, a_3)\cdots\gcd(a_{n-1}, a_n)$. In particular, every geometric sequence $(a^n, a^{n-1}b, a^{n-2}b^2, \ldots, b^n)$ is compound. If we further insist that $\gcd(A) = 1$, then we may form the primitive numerical semigroup minimally generated by A. We study the structure of this semigroup, finding the Apery sets and Frobenius number, and then compute various arithmetic invariants such as catenary degree and delta sets. (Received September 02, 2014)

1106-20-579 **Thomas Michael Keller*** (tk04@txstate.edu), 601 University Drive, San Marcos, TX 78666, and **Yong Yang** (yy10@txstate.edu), 601 University Drive, San Marcos, TX 78666. *Bounding nilpotent and solvable quotients of primitive permutation groups.*

We present some generalizations and extensions of Aschbacher's and Guralnick's 1989 paper on abelian quotients of finite groups. For linear groups we strengthend their bound on $|G/G'|$ in many situations. We also established upper bounds for the sizes of the nilpotent and solvable quotients of primitive permutation groups on a set of size n, which are in the same spirit as the Aschbacher-Guralnick bound for the abelian quotient of such groups. For example, any nilpotent quotient of such a group has order at most n^β, where $\beta = \log 32/\log 9$. (Received September 02, 2014)

1106-20-825 **David Bruce Cohen*** (dc17@rice.edu). *The large scale geometry of strongly aperiodic subshifts of finite type.*

A subshift on a group G is a closed, G-invariant subset of the collection of maps from G to A, for some finite set A. It is said to be of finite type if it is defined by a finite collection of "forbidden patterns". For instance, the set of biinfinite words in some alphabet in which no letter appears three times in a row is a subshift of finite type over the additive group of integers. A subshift of finite type X over G is said to be strongly aperiodic if no element of G has a fixed point in X. We will discuss the question of which groups admit strongly aperiodic subshifts of finite type and how the answer to this question is related to the large scale geometry of groups. (Received September 07, 2014)

1106-20-863 **Matthew D Welz*** (mwelz@uwsp.edu). *Characterizations of Finite Groups with p-fusion of Squarefree Type.*

For G a finite group and p a prime, we discuss two theorems under hypotheses that restrict the index of the subgroup generated by every p-element x in certain subgroups generated by pairs of its conjugates. Under one set of hypotheses, G is shown to be supersolvable. Simple groups satisfying a complementary fusion-theoretic hypothesis are classified as well. (Received September 08, 2014)

1106-20-890 **Volker Diekert*** (diekert@fmi.uni-stuttgart.de), Universitaetsstrasse 38, 70569 Stuttgart, Germany. *Conjugacy in Baumslag's group, generic case complexity, and division in power circuits.*

In my talk I will report on a recent joint work with Alexei Myasnikov and Armin Weiß. The motivation stems from algorithmic group theory. It concerns the conjugacy problem for two prominent groups: the Baumslag-Solitar group BS(1,2) and the Baumslag's group BG(1,2). The groups are quite different although the second one, B(1,2) is still a one-relator group and obtained by a single HNN extension of the Baumslag-Solitar group BS(1,2). The word problem and the conjugacy problem in the Baumslag-Solitar group is easy, but this does not transfer to BG(1,2).

Our main result shows that conjugacy in BG(1,2) can be solved in polynomial time in a strongly generic setting. The result is surprising because our algorithm has non-elementary average case complexity; and we conjecture that this is the best we can expect. This is interesting in a broader sense since it relates a natural conjugacy problem in algorithmic group theory to integer division in power circuits. A power circuit is a data structure which allows to represent huge numbers involving tower functions by small graphs. Actually, the complexity of the division problem in power circuits is an open and interesting problem in arithmetic. (Received September 08, 2014)

1106-20-1069 **Lisa Bromberg** and **Vladimir Shpilrain***, shpil@groups.sci.ccny.cuny.edu, and **Alina Vdovina**. *Navigating the Cayley graph of $SL_2(F_p)$ and applications to hashing.*

Hashing with matrices refers to a simple idea of using a pair of matrices, A and B, to hash the 0 and 1 bit, respectively, and then to hash an arbitrary bit string in the natural way, by using multiplication of matrices. Since there are many known pairs of 2×2 matrices over Z that generate a free monoid, this yields numerous pairs of matrices over F_p, for sufficiently large primes p, that are candidates for collision-resistant hashing. However, this trick can "backfire", and lifting matrix entries to Z may facilitate finding a collision. This "lifting attack" was successfully used by Tillich and Zémor in the special case where two matrices A and B generate (as a monoid) the whole $SL_2(Z)$. However, we show that the situation with other, "similar", pairs of matrices from $SL_2(Z)$ is different, and the "lifting attack" can (in some cases) produce collisions in the *group* generated by A and B, but not in the positive *monoid*. Therefore, we argue that for these pairs of matrices, there are no known attacks at this time that would affect security of the corresponding hash functions. We also give explicit lower bounds on the length of collisions for hash functions corresponding to some particular pairs of matrices from $SL_2(F_p)$. (Received September 10, 2014)

1106-20-1128 **Michael A. Jackson*** (majackson@gcc.edu). *The strong symmetric genus of some small generalized symmetric groups.* Preliminary report.

The strong symmetric genus of a finite group G is the smallest genus of a closed orientable topological surface on which G acts faithfully as a group of orientation preserving symmetries. A generalized symmetric group is a wreath product of a cyclic group of m elements by the symmetric group on n letters, $G(n,m) = C_m \wr S_n$. The strong symmetric genus is known for generalized symmetric groups for small m: the case of the symmetric groups ($m = 1$) was done by Marston Conder, while the cases for $m = 2$ (the hyperoctahedral groups) and $m = 3$ are results by the author. M. Ginter, S. Johnson, and J. McNamara found the strong symmetric genus for the generalized symmetric groups $G(n,m)$ where $n \leq 5$. In this talk we will look at other cases of the strong symmetric genus of the generalized symmetric groups $G(n,m)$ for small n. (Received September 10, 2014)

1106-20-1147 **Laura Ciobanu*** (laura.ciobanu@unine.ch), Rue Emile-Argand 11, 2000 Neuchâtel, Switzerland, and **Yago Antolín**, **Susan Hermiller**, **Derek Holt** and **Sarah Rees**. *On the rationality of the conjugacy growth series in hyperbolic groups.* Preliminary report.

In any group G with finite generating set X consider a set L of conjugacy normal forms. That is, L contains exactly one element w out of each conjugacy class, chosen to be shortest among all the words, over X, that represent group elements in the same conjugacy class as w.

Rivin conjectured that the growth series of L for a hyperbolic group is rational if and only if the group is virtually cyclic. We will present the proof confirming this conjecture. The direction involving virtually cyclic groups is joint work with Susan Hermiller, Derek Holt and Sarah Rees, and the other direction is joint work with Yago Antolín. (Received September 11, 2014)

1106-20-1161 **Markus Lohrey*** (lohrey@eti.uni-siegen.de). *Knapsack problems for nilpotent groups.*

Recently, Myasnikov, Nikolaev and Ushakov considered classical knapsack related decision problems for arbitrary finitely generated (f.g.) groups. Among others, they studied the following problems for a f.g. group G (where elements of G are represented by finite words over the generators):

- Subset sum problem for G: Given $g_1, \dots, g_k, g \in G$, decide whether there exist $\varepsilon_1, \dots, \varepsilon_k \in \{0,1\}$ such that $g = g_1^{\varepsilon_1} \cdots g_k^{\varepsilon_k}$.
- Knapsack problem for G: Given $g_1, \dots, g_k, g \in G$, decide whether there exist natural numbers $\varepsilon_1, \dots, \varepsilon_k \geq 0$ such that $g = g_1^{\varepsilon_1} \cdots g_k^{\varepsilon_k}$.

Among other results, Myasnikov et al. proved that for a f.g. virtually nilpotent group the subset sum problem can be solved in polynomial time.

We show that (i) there exists a f.g. 2-step nilpotent group G with an undecidable knapsack problem and (ii) that for every f.g. virtually nilpotent group the subset sum problem belongs to nondeterministic logarithmic space (a subclass of deterministic polynomial time). We conjecture that the subset sum problem for a f.g. virtually nilpotent group can be solved in deterministic logarithmic space. (Received September 11, 2014)

1106-20-1163 **Zoran Sunic*** (sunic@math.tamu.edu). *Ordering trees, free groups, and free products.*

We provide a construction of orders on free groups that are easy to describe and work with. In particular, the positive cone is a context-free language (in fact, a one-counter language), which can be described as the set of elements with positive value under certain counting quasi-morphisms. We show how to construct Cantor sets of orders with various properties (for instance, all of them extending the standard lexicographical order on the positive monoid). Finally, we provide a simple proof of Vinogradov's result showing that the free product of left orderable groups is left-orderable (the last result is a joint work with Warren Dicks). (Received September 11, 2014)

1106-20-1353 **Laxmi K Chataut*** (lkchataut@crimson.ua.edu). *Groups with the weak minimal condition on non-permutable subgroups.* Preliminary report.

Let H be a subgroup of a group G. Then H said to be *permutable* if it permutes with every subgroup of G, that is, $HK = KH$ for every subgroup K of G. Let $\mathcal{P}$ be a subgroup theoretical property or class of groups, then $\bar{\mathcal{P}}$ is the class of all groups that either are not-$\mathcal{P}$ groups or are trivial. A group G is said to satisfy the *weak minimal condition on* $\mathcal{P}$*- subgroups* (denoted by min-∞-$\mathcal{P}$) if for every descending chain $H_1 > H_2 > H_3 > \cdots$ of $\mathcal{P}$ subgroups of G , $|H_i : H_{i+1}|$ is infinite for only finitely many i. Thus, for example, on letting $\mathcal{P}$ denotes the class of permutable subgroups, we may speak of groups satisfy min-∞-$\bar{\mathcal{P}}$, the weak minimal condition on non-permutable subgroups. Groups with this property are the subject of our interest.The main results are as follows; If G is a locally finite group satisfying the weak minimal condition on non-permutable subgroups then either G is Chernikov or every subgroup of G is permutable. It is also proved that for a radical group G satisfying the weak minimal condition on non-permutable subgroups either G has *finite rank* or every subgroup of G is permutable. (Received September 12, 2014)

1106-20-1520 **Dmytro M Savchuk*** (savchuk@usf.edu), Department of Mathematics and Statistics, Unviersity of South Florida, 4202 E Fowler Ave, CMC 342, Tampa, FL 33620, **Ines Klimann** (klimann@liafa.univ-paris-diderot.fr), LIAFA - Université Paris Diderot-Paris7, Case 7014, F-75205, Paris, France, and **Matthieu Picantin** (picantin@liafa.univ-paris-diderot.fr), LIAFA - Université Paris Diderot-Paris7, Case 7014, F-75205, Paris, France. *Orbit automata as a new tool to attack finiteness problem for automaton groups.* Preliminary report.

We introduce a new tool, called the orbit automaton, that describes the action of an automaton group G on the subtrees corresponding to the orbits of G on levels of the tree. In particular, we provide the connection between G and the group generated by the orbit automaton and use it to deduce infiniteness of some automaton groups for which other methods did not work. Further, we show that for each automaton group there is only finite number of different orbit automata up to equivalence. (Received September 13, 2014)

1106-20-1570 **Andrew Sale*** (andrew.sale@some.oxon.org). *A geometric approach to the conjugacy search problem: the conjugacy length function.*

Given a pair of conjugate elements u, v in a group, the conjugacy length function determines an upper bound on the size of shortest group element g such that gu is equal to vg. Such a function can be used when determining the complexity of the conjugacy search function. I will describe some recent results concerning the nature of the conjugacy length function in some families of groups. (Received September 14, 2014)

1106-20-1573 **Laura Ciobanu** (laura.ciobanu@unine.ch), Mathematics Department, University of Neuchâtel, Rue Emile-Argand 11, CH-2000 Neuchâtel, Switzerland, **Susan Hermiller*** (smh@math.unl.edu), Department of Mathematics, University of Nebraska, Lincoln, NE 68588-0130, **Derek Holt** (d.f.holt@warwick.ac.uk), Mathematics Institute, Zeeman Building, University of Warwick, Coventry, CV4 7AL, United Kingdom, and **Sarah Rees** (sarah.rees@ncl.ac.uk), Department of Mathematics, University of Newcastle, Newcastle, NE1 7RU, United Kingdom. *Conjugacy languages in groups.*

Regularity of languages derived from conjugacy classes in a finitely generated group G implies rationality of the corresponding growth series. In this talk I will discuss regularity for languages of conjugacy geodesics and geodesic normal forms for conjugacy classes and elements of minimal length up to conjugacy, for a variety of examples including word hyperbolic, virtually abelian, Artin, and Garside groups. (Received September 14, 2014)

1106-20-1598 **Paul Baginski*** (pbaginski@fairfield.edu), Fairfield University, Department of Mathematics, 1073 North Benson Rd, Fairfield, CT 06824, and **Abraham Bekele**, **Katie Lynn Rosenberg** and **Benjamin Wright**. *New Developments for the Plus-Minus Davenport Constant.* Preliminary report.

Let G be a finite abelian group. The classical and extensively studied Davenport constant $D(G)$ is the least integer n such that any sequence $S = g_1, g_2, \ldots, g_n$ of n elements of G has a nonempty, zero-sum subsequence, i.e. $\sum_{i\in I} g_i = 0$ for some nonempty $I \subseteq \{1, \ldots, n\}$. An elementary argument shows $D^*(G) \leq D(G) \leq |G|$ for a constant $D^*(G)$ defined simply from the standard decomposition of G as a sum of cyclic groups. While the lower bound is not sharp, it is the correct value in most cases where the exact value of $D(G)$ is known, such as groups of rank ≤ 2 and p-groups.

Recently, several authors have added weights to this zero-sum problem. We concentrate on weights 1 and -1. The plus-minus Davenport constant $D_\pm(G)$ to be the least integer n such that for any sequence $S = g_1, g_2, \ldots, g_n$ of n elements of G, there exist $a_i \in \{-1, 0, 1\}$ not all zero such that $\sum_{i=1}^n a_i g_i = 0$. Values are known for far fewer groups, but the known general upper and lower bounds are far closer than for the classical Davenport constant, giving hope that this problem may be more tractable. We will review previous efforts and describe recent progress from the Fairfield University REU during summer 2014. (Received September 14, 2014)

1106-20-1616 **Conchita Martinez-Perez*** (conmar@unizar.es), Departamento de matemáticas, Universidad de Zaragoza, 50002 Zaragoza, Zaragoza, Spain. *The proper geometric dimension of Coxeter groups.*

We use compactly supported cohomology to derive a formula for the proper geometric dimension of groups admitting a cocompact classifying space for proper actions. Using this formula, we show that the proper geometric dimension of some groups including Coxeter groups equals its virtual cohomological dimension. We will also review some other famiies having this property. (Received September 14, 2014)

1106-20-1660 **Joshua Wiscons*** (jwiscons@hamilton.edu). *Recognizing* PGL_3 *via generic 4-transitivity.* Preliminary report.

The groups of finite Morley rank form a class of groups equipped with a model-theoretic notion of dimension generalizing the affine algebraic groups over algebraically closed fields. Recently, Borovik and Cherlin initiated a broad study of permutation groups of finite Morley rank where one of the main problems is to show that there is a natural upper bound on the degree of *generic* transitivity of such a permutation group that depends only upon the rank of the set being acted on. Such a bound has been known for a few decades when the set being acted on has rank 1, and this talk will present recent work, joint with Tuna Altınel, addressing the case of rank 2. (Received September 14, 2014)

1106-20-1667 **Mark Sapir*** (m.sapir@vanderbilt.edu), Vanderbilt University. *Tarski numbers of groups.*

The Tarski number of a non-amenable group is the minimal number of pieces in a paradoxical decomposition. We show how to construct (2-generated) non-amenable groups with arbitrary large Tarski numbers and also groups with Tarski numbers 5 and 6. This is a joint work with M. Ershov and G. Golan (Received September 14, 2014)

1106-20-1684 **Alexandre Turull*** (turull@ufl.edu), Department of Mathematics, University of Florida, Gainesville, FL 32611. *Modifying and combining endoisomorphisms.* Preliminary report.

Character and module correspondences play a important role in the representation theory of finite groups. Each endoisomorphism gives rise to a unique family of module and character correspondences over many related groups and over many fields. In this talk, we will discuss how one can modify and combine different endoisomorphisms and what effect these modifications and combinations have on the corresponding module and character correspondences. These elementary properties of endoisomorphisms provide useful tools for proofs in representation theory of finite groups. (Received September 15, 2014)

1106-20-1717 **Sarah B Mason*** (sbmason@ncsu.edu), Cary, NC 27518. *Conjugacy Classes of θ-stable, maximal k-split tori invariant under involutions of $SL(n,k)$.*

Maximal k-split tori invariant under an involution are of fundamental importance in the characterization of parabolic k-subgroups acting on symmetric spaces. In this talk, we consider symmetric spaces for SL_n and give a detailed characterization of tori under the action of the fixed point group of the involution defining the symmetric space. (Received September 15, 2014)

1106-20-1734 **Keith Jones** (keith.jones@oneonta.edu), Department of Mathematics, State University of New York at Oneonta, 108 Ravine Parkway, Oneonta, NY 13820, and **Gregory A. Kelsey*** (gregory.kelsey@trincoll.edu), Department of Mathematics, Trinity College, 300 Summit St., Hartford, CT 06106. *The horofunction boundary of the lamplighter group with the Diestel-Leader metric.*

The horofunction boundary of a proper metric space X is formed by embedding it in $C(X)$ and taking the closure. We fully describe the horofunction boundary of a Cayley graph for the lamplighter group (the Diestel-Leader graph $DL(2,2)$). This boundary can be partitioned into several sets which are invariant under the action of the lamplighter group. Two of these sets have union equal to the visual boundary of the group. Two of these sets consist of only a single point each, which gives that the action of the lamplighter group on this horofunction boundary has two global fixed points. These global fixed points are the functions that map a lamp stand to the position of its lamplighter, and its negation. (Received September 15, 2014)

1106-20-1738 **Nathan Kaplan*** (nathan.kaplan@yale.edu), Yale University, Department of Mathematics, 10 Hillhouse Avenue, New Haven, CT 06511, and **Stefan Colton**. *The Realization Problem for Delta Sets of Numerical Semigroups.*

The delta set of a numerical semigroup is a factorization invariant that measures the complexity of the sets of lengths of its elements. We study the following two problems: Which finite sets occur as delta sets? If we restrict to semigroups with minimal generating set of size e, which finite sets occur as delta sets?

It is known that the minimum element of a delta set must be equal to the gcd of its elements. We show that any two-element set $\{d, td\}$ occurs as a delta set. We also show that if the two-element set $\{d, td\}$ occurs as the delta set of a numerical semigroup with three minimal generators, then $t = 2$. (Received September 15, 2014)

1106-20-1813 **Hung Cong Tran*** (hctran@uwm.edu). *Relative divergence of finitely generated groups.*

We generalize the concept of divergence of finitely generated groups by introducing the upper and lower relative divergence of a finitely generated group with respect to a subgroup. Upper relative divergence generalizes Gersten's notion of divergence, and lower relative divergence generalizes a definition of Cooper-Mihalik. While the lower divergence of Cooper-Mihalik can only be linear or exponential, relative lower divergence can be any polynomial or exponential function. We examine the relative divergence (both upper and lower) of a group with respect to a normal subgroup or a cyclic subgroup. We also explore relative divergence of $CAT(0)$ groups and relatively hyperbolic groups with respect to various subgroups to better understand geometric properties of these groups. (Received September 15, 2014)

1106-20-1924 **Jonathan I Hall*** (jhall@math.msu.edu), Department of Mathematics, Michigan State University, 619 Red Cedar Road, East Lansing, MI 48824. *Groups and nonassociative algebra.*

Group theory, particularly that of finite groups, has been used successfully to describe and classify interesting nonassociative structures. We will discuss abstract groups with triality and their relationship with Moufang loops and Miyamoto tranposition groups and their relationship with axial algebras and vertex operator algebras. (Received September 15, 2014)

1106-20-2125 **John H. Johnson*** (johnson.5316@osu.edu). *An algebraic proof of Szeméredi's affine cube lemma via ultrafilters.* Preliminary report.

Szeméredi's affine cube lemma states that for every real number $\delta > 0$ and every positive integer m there exists a positive integer N such that if $A \subseteq \{1, 2, \ldots, N\}$ with $|A| \geq \delta \cdot N$, then there exists a finite sequence of positive integers $\langle a_n \rangle_{n=0}^{m}$ such that $a_0 + \left\{\sum_{i \in F} a_i \mid \emptyset \neq F \subseteq \{1, 2, \ldots, m\}\right\} \subseteq A$. Szeméredi's proved this lemma as one important component of his combinatorial proof that "dense" subsets of a sufficiently long interval of positive integers contains a 4-term arithmetic progression. I'll give a short and simple proof, which is similar to the ultrafilter proof of Hindman's finite sums theorem, of the affine cube lemma using the algebraic structure of the Stone-Čech compactification of the positive integers. (Received September 15, 2014)

1106-20-2143 **Ethan Kowalenko*** (ekowalen@msudenver.edu). *Extending the Euclidean Dimension of Spinpossible.* Preliminary report.

Spinpossible is a game played on a 3×3 board, where the natural numbers up through 9 are bijectively mapped with the possibility of inverted orientation. Given any starting board, the goal of the game is to spin rectangles on the board by 180° in order to arrive at the identity board, and to do it in a minimum number of spins. The set of all possible boards can be represented by the Coxeter group B_9 under a non-standard generating set, i.e., the spins. So far, we have analyzed Spinpossible in the hopes of optimizing solutions to random boards, using methods from graph theory, group theory, and metric spaces.

This game easily generalizes to any $m \times n$ board, $m \leq n$. Noting this, we call a board one-dimensional if $m = 1$, and two dimensional otherwise. In this talk, we will show a combinatorial solution to the 2×2 boards, as well as the solution from Hannenhali and Pevznor for one-dimensional boards. We will then discuss how we can extend the definitions of Spinpossible to d-dimensions, and determine what lower dimensional machinery is affected by this extension. (Received September 15, 2014)

1106-20-2387 **Michael Kinyon*** (mkinyon@du.edu), Department of Mathematics, 2280 S. Vine St, University of Denver, Denver, CO 80208. *Automorphic Loops and their Permutation Groups.*

An important permutation group associated with a loop Q is its multiplication group $\mathrm{Mlt}(Q)$ generated by all left translations $L_x : y \mapsto xy$ and all right translations $R_x : y \mapsto yx$. The stabilizer of the identity element of Q is the inner mapping group $\mathrm{Inn}(Q)$. A loop is *automorphic* if every inner mapping is an automorphism of Q. Groups and commutative Moufang loops are examples of automorphic loops, but there are many others as well.

The outstanding open problem in the theory of automorphic is to determine if there are any finite, nonassociative, simple automorphic loops. Simplicity of a loop Q is characterized by $\mathrm{Mlt}(Q)$ acting primitively on Q, and thus one approach to searching for simple loops is to use the O'Nan-Scott classification.

In this talk, I will describe the current state of the art in the search for finite, nonassociative, simple automorphic loops. This is joint work with many people, most recently Peter Cameron and Dimitri Leemans. (Received September 16, 2014)

1106-20-2401 **David Garber*** (garber@hit.ac.il), 52 Golomb St., PO Box 305, 5810201 Holon, Israel, and **Arkadius Kalka**, **Eran Liberman** and **Mina Teicher**. *Centralizers of centralizers of parabolic subgroups of braid groups and its application to the conjugacy problem.*

We characterize the centralizer of the centralizer of all parabolic subgroups of the braid groups. We apply this result to provide a new and potentially more efficient solution to the subgroup conjugacy problem for these parabolic subgroups. (Received September 16, 2014)

1106-20-2597 **Briana Foster-Greenwood*** (fostbria@isu.edu) and **Cathy Kriloff** (krilcath@isu.edu). *Distance Spectra of Cayley Graphs of Complex Reflection Groups.*

We consider Cayley graphs of complex reflection groups with vertices labeled by group elements and edges corresponding to multiplication by any reflection in the group. Extending the work of P. Renteln for real reflection groups to all finite complex reflection groups, we show the distance matrix (recording lengths of shortest paths between any two group elements) has all integer eigenvalues. The key representation theoretic perspective from the real case persists, but in the general complex case, a discrepancy between geometry (codimension of fixed point spaces) and group structure (reflection length) prompts an analysis of reflection-preserving group automorphisms, and, in a finite number of cases, computer calculations with the software GAP. (Received September 16, 2014)

1106-20-2613 **Alexander F. Card***, WCM 222, University of Central Missouri, Warrensburg, MO 64093. *Monotone Catenary Degrees for Small Groups.* Preliminary report.

Let G be a finite abelian group. The block monoid of G is the set $\mathcal{B}(G)$ of zero-sum sequences $g_1 \cdots g_n$ such that $\sum_{i=1}^{n} g_i = 0$ with the operation given by concatenation. A factorization $z = \alpha_1 \cdot \ldots \cdot \alpha_n$ of length $|z| = n$ of an element $\alpha \in \mathcal{B}(G)$ is a product of n atoms of $\mathcal{B}(G)$; that is, zero-sum sequences which contain no proper zero-sum subsequences. The monotone catenary degree $\mathsf{c}_{\mathrm{mon}}(G)$ is the smallest $m \in \mathbb{N}_0 \cup \{\infty\}$ such that for each $\alpha \in \mathcal{B}(G)$ and every pair of factorizations z, z' of α where $|z| \leq |z'|$, there is a chain $z = z_0, z_1, \ldots, z_k = z'$ of factorizations of α with $|z_i| \leq |z_{i+1}|$ $\forall i$ where z_{i+1} is constructed from z_i by replacing at most m atoms from

z_i with at most m new atoms. In a recent paper Geroldinger and Yuan provide explicit upper and lower bounds for $\mathsf{c}_{\mathrm{mon}}(G)$. They leave open exact values for cyclic groups and the following groups:

$$C_2^3, C_2^4, C_3^2, C_3^3, C_3^4, C_3^5, C_2 \oplus C_4, C_2 \oplus C_6.$$

We investigate, using theoretical and computational techniques $\mathsf{c}_{\mathrm{mon}}(G)$ where G is one of these exceptional groups. (Received September 16, 2014)

1106-20-2786 **Bumsoo Kim*** (bumsook@princeton.edu), Frist 0574, Princeton University, Princeton, NJ 08544. *The Cross Number of Zero-sum Free Sequences in Finite Abelian Groups.*

We study the maximal cross number $\mathsf{k}(G)$ of a zero-sum free sequence over a finite abelian group G, defined by Krause and Zahlten. In the first part of this paper, we extend a previous result by X. He to prove that the value of $\mathsf{k}(G)$ conjectured by Krause and Zahlten hold for $G \bigoplus C_{p^a} \bigoplus C_{p^b}$ when it holds for G. In the second part, we describe a new method for proving that the conjectured value of $\mathsf{k}(G)$ hold for abelian groups of the form $H_p \bigoplus C_{q^m}$ (where H_p is any finite abelian p-group) and $C_p \bigoplus C_q \bigoplus C_r$ for any distinct primes p, q, r. (Received September 16, 2014)

1106-20-2790 **Anders O.F. Hendrickson*** (anders.hendrickson@snc.edu), Department of Mathematics, St. Norbert College, 100 Grant St, De Pere, WI 54115. *Some recent advances in lattices of supercharacter theories.*

The set of supercharacter theories of a finite group forms a lattice. We relate some recent advances in understanding the structure of these lattices. (Received September 16, 2014)

1106-20-2791 **Nathan Corwin*** (nacorwin@math.rutgers.edu) and **Kathryn Haymaker** (kathryn.haymaker@villanova.edu). *Graph Products of Groups in Thompson's group V.* Preliminary report.

Richard Thompson's group V is one of the first known examples of a finitely presented infinite simple group. Despite being discovered by Thompson in 1965, much of its structure is still unknown. In 2009 Bleak and Salazar-Diaz proved that $\mathbb{Z} * \mathbb{Z}^2$ does not embed into V. This was a surprising result, partially because it was widely assumed that all graph products of groups embedded into V.

We classify all graphs with a particular forbidden subgraph related to $\mathbb{Z} * \mathbb{Z}^2$. As a consequence, we establish exactly which graph products embed into V. (Received September 16, 2014)

1106-20-2802 **Thomas Langley*** (langley@rose-hulman.edu). *Generalizations of commutativity in finite groups.* Preliminary report.

The probability that two randomly selected elements of a non-Abelian finite group commute is at most 5/8, and this bound is tight when the center of the group is as large as possible. We investigate several generalizations of commutativity that lead to variations of the 5/8 bound, in particular the probability that a product of n group elements is equal to its reverse, to a cyclic rearrangement of itself, or to an arbitrary permutation or signed permutation of itself. We also study how these generalized bounds behave when the center of a group is small instead of large. (Received September 16, 2014)

22 ► Topological groups, Lie groups

1106-22-182 **William Graham** and **Wenjing Li***, wliwmath@gmail.com. *The Smooth Locus of Spiral Schubert Varieties of type $\tilde{A}_2$.*

One interesting problem in the study of Schubert varieties is to determine the set of points where the Schubert variety is smooth. We describe the smooth locus of an interesting family of Schubert varieties called spiral Schubert varieties in the case of affine A_2. We do this by using some root system facts, to calculate equivariant multiplicities of spiral Schubert varieties at certain rationally smooth points. (Received August 05, 2014)

1106-22-458 **Vicky W Klima*** (klimavw@appstate.edu). *Generalized Symmetric Spaces of SL(2) over Finite Fields.*

Symmetric spaces play a key role in many fields of active research such as Lie theory, differential geometry, and harmonic analysis. More recently, generalized symmetric spaces have become of interest in representation theory. Any involution of an algebraic group gives rise to both a generalized and extended symmetric space for that group. For the special linear group with real entries, the generalized symmetric space consists of the symmetric positive definite matrices while the extended symmetric space contains all symmetric matrices. In general, the extended symmetric space contains the generalized symmetric space and typically this containment is proper.

We will show that in the case of SL(2) with entries in a finite field of characteristic not equal to two, this typical behavior does not hold; the generalized and extended symmetric spaces are equal independent of the choice of involution. The talk will end with a discussion of undergraduate investigations into the structure of the extended symmetric space for the symmetric group via poset diagrams. (Received August 28, 2014)

1106-22-643 **Paul Frank Baum*** (baum@math.psu.edu), Department of Mathematics, Penn State University, Univesity Park, PA 16802. *Free actions of compact quantum groups.*

A compact quantum group is a unital C^* algebra with a given comultiplication.

THEOREM.(Baum-Hajac-DeCommer) Let G be a compact quantum group acting on a unital C^* algebra A. Then the action is free if and only if the action of the underlying Hopf algebra of G on the Peter-Weyl subalgebra of A satisfies the Peter-Weyl-Galois condition (i.e. the canonical map is bijective).

This talk will outline the proof in the classical case of a compact Hausdorff group G acting on a compact Hausdorf topological space X, and will then indicate how this proof can be modified to apply to the quantum case.

The above is joint work with Piotr Hajac and Kenny DeCommer. (Received September 03, 2014)

1106-22-1014 **Daniel Bump*** (bump@math.stanford.edu). *Quantum Groups and Whittaker Functions.*

Tokuyama's formula is a deformation of the Weyl character formula (for type A). It generalizes to formulas for p-adic Whittaker functions. On the other hand, some well-known cases of Yang-Baxter equation, which is a tool for proving similar formulas, follow from the fact that the Hopf algebra $U_q(\mathfrak{sl}_2)$ is "quasitriangular." Brubaker, Bump and Friedberg gave a proof of Tokuyama's formula using a more general form of the Yang-Baxter equation (also found by Korepin) in the special case where $q = \sqrt{-1}$. This strongly suggests that $U_q(\mathfrak{sl}_2)$ (or its dual Hopf algebra) can be enlarged when $q = \sqrt{-1}$. Such an enlargement was constructed by Valentin Buciumas in his dissertation. We will report on these and related matters. (Received September 09, 2014)

1106-22-1043 **Joanna Furno**, **James Keesling*** (kees@ufl.edu) and **James Maissen**. *Applications of topological group actions on Hilbert space.* Preliminary report.

Let Δ_p be the $p-$adic group. There is a free action of Δ_p on separable infinite-dimensional Hilbert space. The simplest construction of such an action is by using the space of measurable functions to Δ_p, $\mathcal{M}([0,1],\Delta_p)$. This space is homeomorphic to separable infinite-dimensional Hilbert space. It is a topological group from the topological group structure on Δ_p. The group Δ_p is a subgroup and hence acts freely on $\mathcal{M}([0,1],\Delta_p)$.

In this talk we investigate this group action and give some applications. Among other results we show that this group action is universal for a large collection of free $p-$adic group actions on separable metric spaces. (Received September 10, 2014)

1106-22-1091 **Arielle M Leitner*** (aleitner@math.ucsb.edu), 6510 El Colegio Rd, Apt 1103, Santa Barbara, CA 93106. *Conjugacy Limits of the Group of Diagonal Matrices.*

A *geometric transition* is a continuous path of geometries which abruptly changes type in the limit. In this project, we explore geometric transitions of the Cartan subgroup in $SL_n(\mathbb{R})$. For $n = 3$, it turns out the Cartan subgroup has precisely 5 limits, and for $n = 4$, there are 15 limits, which give rise to *generalized cusps* on convex projective 3-manifolds. (Received September 10, 2014)

1106-22-1666 **Milen Yakimov*** (yakimov@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70808, and **Tom Lenagan**. *Clusters for quantum Richardson varieties.*

Quantized coordinate rings of open Richardson varieties can be realized in terms of prime quotients of quantum Schubert cell algebras. We will explain how initial quantum clusters for them can be constructed using Cauchon's method of deleting derivations. Apart from the problem of constructing cluster algebra structures on quantum Richardson varieties, this also has applications to the realization of the orbit method for quantized universal enveloping algebras of nilpotent Lie algebras. (Received September 14, 2014)

1106-22-1901 **Jose A Franco***, Department of Mathematics & Statistics, University of North Florida, 1 UNF Dr., Jacksonville, FL 32224. *Global Actions of the Symmetry Group of the n-dimensional Porous Medium Equation.*

The actions of the symmetry group of the n-dimensional porous medium equation

$$u_t = \Delta_n(u^m)$$

are globalized on a special class of functions. The globalization is attained by using parabolic induction on the group $G = SL(2,R) \times SO(1,n+1)_0$ where the 0 sub-index denotes the connected component. (Received September 15, 2014)

1106-22-2666 **Arielle M Leitner*** (aleitner@math.ucsb.edu), 6510 El Colegio Rd, Apartment 1103, Santa Barbara, CA 93106. *Geometric Transitions of the Group of Diagonal Matrices.*

A *geometric transition* is a continuous path of geometries which abruptly changes type in the limit. We explore geometric transitions of the Cartan subgroup in $SL_n(\mathbb{R})$. For $n = 3$, it turns out the Cartan subgroup has precisely 5 limits, and for $n = 4$, there are 15 limits. For $n \geq 7$, it turns out that there is a continuum of non conjugate limits! (Received September 16, 2014)

1106-22-2860 **Jonathan Francis Fernandes*** (jonathan712@gmail.com), 3412 Tulane Drive, 22, Hyattsville, MD 20783. *Computing hermitian forms.* Preliminary report.

In this talk we will show how one constructs hermitian forms on representations of real reductive groups. There is a well known algorithm due to Adams, Vogan, Trapa et al. We shall work out some examples explicitly for some specific split real groups. The main goal is to outline a procedure for finding new unitary representations. (Received September 16, 2014)

26 ► Real functions

1106-26-407 **Zengtai Gong**, College of mathematics and stattiscas sciences, Northwest Normal University, Lanzhou, 730070, P. R. China, **Lu Zhang**, Department of Basic Teaching, Shanxi Technology and Basiness College, Taiyuan, 030006, P. R. China, and **Xinyun Zhu*** (zhu_x@utpb.edu), University of Texas of the Permian Basin, Odessa, TX 79762. *The Statistical convergence for sequences of fuzzy-number-valued functions.* Preliminary report.

Based on the concept of statistical convergence of sequences of fuzzy numbers, the statistical convergence, uniformly statistical convergence and equi-statistical convergence of sequences of fuzzy-number-valued functions are defined and investigated in this paper. The relationship among statistical convergence, uniformly statistical convergence and equi-statistical convergence of sequences of fuzzy-number-valued functions and their representations of sequences of α-level cuts are discussed. In addition, the Egorov and Lebesgue Theorems for the statistical convergence of sequences of fuzzy-number-valued functions are obtained in a finite measure set. Finally, the statistical convergence in measure for sequences of fuzzy-number-valued functions is investigated, and it is proved that the outer and inner statistical convergence in measure are equivalent in a finite measure set for a sequence of fuzzy-number-valued functions. (Received August 27, 2014)

1106-26-1358 **Paul Eloe*** (peloe1@udayton.edu), **Jeffrey Lyons** and **Jeffrey Neugebauer**. *Comparisons of Green's Functions for Multiple Term Fractional Differential Equations.*

Recent progress has been made in the study of boundary value problems for multiple term fractional differential equations. In particular, there are recent advances in the study of

$$-D^{\alpha}_{0+}u + aD^{\beta}_{0+}u = f(t,u),$$

with Dirichlet boundary conditions, where D^{α}_{0+} or D^{β}_{0+} represent Riemann-Liouville fractional derivatives. We shall study families of boundary value problems associated with a multiple term fractional differential equation and obtain maximum principles and comparisons of corresponding Green's functions. (Received September 12, 2014)

1106-26-1438 **Roberto J Perez*** (roberto.perez11@upr.edu), P.O. Box #817, Vega Baja, PR 00694, and **Megan Brunner**, **Natalie Wiens** and **Nathan Albin**. *The Modulus Function of Walk Families.*

The modulus of a family of walks on a weighted undirected graph provides a quantitative assessment of the "richness" of the family. The modulus is computed by minimizing an energy function over a set of admissible metrics on the graph. In certain special cases, the modulus generalizes the concepts of shortest path, minimum cut, and effective resistance. This paper explores continuity properties of the modulus and the associated extremal graph metrics. It then extends to look at the modulus of long walks on linear graphs and balanced trees. (Received September 13, 2014)

1106-26-1604 **Fred Halpern*** (fredhalp@gmail.com). *From Discrete to Analytic Inequality.* Preliminary report.

Mathematical folklore suggests that many discrete inequalities have analytic analogs. We formalize this intuition with a methodology that systematically provides a large class of discrete inequalities with analytic analogs.

A key insight is we must start with a very general inequality valid for all n and all collections of n-sequences. The generality yields inequalities that can be manipulated to provide a uniform system of inequalities between

Riemann sums. We state a theorem with the Holder (Cauchy–Schwarz) and Minkowski inequalities as special cases. It also yields an Analytic analogue to the Arithmetic-Geometric Mean inequality with specific interesting examples.

The collections of n-sequences can be restricted by conditions on the sequences (positive, monotone, convex) if the corresponding condition on functions yield Riemann sums.whose terms satisfy the condition. The corresponding theorem has Jensen's and Chebyshev's sum inequalities as corollaries.

The method also yields double integral of two variable functions inequalities corresponding to double sums of doubly indexed sequences inequalities. Minkowski's double sum inequality is an example. It also extends to convolution inequalities with Young's inquality as an example. (Received September 14, 2014)

1106-26-2006 **Dominique Guillot** (dguillot@stanford.edu) and **Bala Rajaratnam*** (brajarat@stanford.edu). *Regularization of positive definite matrices: Connections between linear algebra, graph theory, and statistics.*

Positive definite matrices arise naturally in many areas within mathematics and also feature extensively in scientific applications. In modern high-dimensional applications, a common approach to finding sparse positive definite matrices is to threshold their small off-diagonal elements. This thresholding, sometimes referred to as hard-thresholding, sets small elements to zero. Thresholding has the attractive property that the resulting matrices are sparse, and are thus easier to interpret and work with. In many applications, it is often required, and thus implicitly assumed, that thresholded matrices retain positive definiteness. We formally investigate the (linear) algebraic properties of positive definite matrices which are thresholded. We also undertake a detailed study of soft-thresholding, another important technique used in practice. Some interesting and unexpected results will be presented. Finally, we obtain a full characterization of general maps which preserve positivity when applied to off-diagonal elements, thereby extending previous work by Schoenberg and Rudin. (Joint with D. Guillot) (Received September 15, 2014)

1106-26-2009 **Dominique Guillot*** (dguillot@stanford.edu), **Apoorva Khare** (khare@stanford.edu) and **Bala Rajaratnam** (brajarat@stanford.edu). *Entrywise functions preserving positivity for rank-constrained matrices.*

We consider the problem of characterizing real-valued functions f which preserve positive semidefiniteness when applied entrywise to $n \times n$ matrices. This classical problem has been studied by numerous authors, most notably by Schoenberg and Rudin. One of their most significant results states that f preserves positive semidefinite matrices of all dimensions, if and only if f has a Taylor series with nonnegative coefficients.

In this work, we focus on functions preserving positivity for matrices of a given rank. We are motivated by applications in high-dimensional statistics, where functions are often applied to covariance/correlation matrices to improve their properties. In that setting, the rank corresponds to the sample size and is thus known. We obtain several new characterizations of these functions. Additionally, our techniques apply to classical problems such as the one considered by Schoenberg and Rudin. In contrast to previous work, our approach is transparent, and enables us to provide intuitive, elegant, and enlightening proofs.

(Joint work with A. Khare and B. Rajaratnam) (Received September 15, 2014)

1106-26-2012 **Dominique Guillot** (dguillot@stanford.edu), **Apoorva Khare*** (khare@stanford.edu) and **Bala Rajaratnam** (brajarat@stanford.edu). *Sparse positive definite matrices, graphs, and absolutely monotonic functions.*

We study the problem of characterizing functions, which when applied entrywise, preserve the set of positive semidefinite matrices with zeroes according to a family $\mathcal{G} = \{G_n\}$ of graphs. This refines previous work (by Rudin, Schoenberg, and others), in which the sole family of all complete graphs $\{K_n : n \in \mathbb{N}\}$ was studied, in terms of absolutely monotonic functions. We obtain novel characterizations for $\mathcal{G}$ an arbitrary collection of trees. We further show that analytic functions preserving positivity on matrices with zeros according to trees, can contain arbitrarily long sequences of negative coefficients, thus obviating the need for absolute monotonicity in a very strong sense. Finally, we find a stronger condition for preserving positivity for any sequence of graphs with unbounded maximal degree, which is only satisfied by absolutely monotonic functions. (Joint with Dominique Guillot and Bala Rajaratnam) (Received September 15, 2014)

28 ► Measure and integration

1106-28-1001 **Dan Mauldin***, mauldin@unt.edu. *Some unsolved and recently solved problems from the Scottish Book.* Preliminary report.

The Scottish Book, formulated in the Scottish Cafe in Lvov, Poland mainly during the 1930's, generated many outstanding problems and directions in mathematics. I will discuss some problems from the Scottish Book that have been solved in the past few years including: (1) Fefferman's solution to Problem 15 of Schauder, (2) partial solutions to Ulam's Problem 38 on random directed graphs, (3) von Neumann's problem 163 concerning measures on Boolean algebras and (4) some other partially solved or unsolved problems - time permitting. (Received September 09, 2014)

1106-28-1736 **Mrinal K Roychowdhury*** (roychowdhurymk@utpa.edu), Dept of Mathematics, UTPA, 1201 West University Drive, Edinburg, TX 78539, and **Nina Snigireva**. *Quantization dimension estimate for condensation systems of infinite self-similar mappings.*

I will talk about an inhomogeneous measures μ which is generated by an infinite system of self-similar mappings with the inhomogeneous part a self-similar measure ν. We showed that for all $r \in (0, \infty)$ the lower and the upper quantization dimension of order r of the measure μ are bounded below by the quantization dimension $D_r(\nu)$ of ν and bounded above by a unique number $\kappa_r \in (0, \infty)$ where κ_r has a relationship with the temperature function of the thermodynamic formalism that arises in multifractal analysis of μ. (Received September 15, 2014)

30 ► Functions of a complex variable

1106-30-81 **Yusuf Abu-Muhanna** and **Rosihan M Ali*** (rosihan@cs.usm.my), School of Mathematical Sciences, Universiti Sains Malaysia, 11800 Penang, Malaysia. *Distortion estimates for harmonic univalent maps.*

New distortion estimates in terms of the hyperbolic metric are obtained for harmonic univalent maps $f = h + \overline{g}$, with h and g analytic in the unit disk. An estimate for the second coefficient is also obtained for functions h mapping the unit disk onto a hyperbolic domain, which as a consequence, yields a vastly improved second coefficient estimate for harmonic functions f. (Received July 05, 2014)

1106-30-166 **Lawrence J. Crone*** (lcrone@centurylink.net), 463 Walters Hollow Road, Alum Bank, PA 15521. *Convergence to Fixed Cycles and the Inverse Schroder Function.*

Let f be a quadratic rational function with a repelling fixed point at the origin, and let G be the inverse of the classical Schroder function. Color graphs of G reflect the presence of attractive fixed points and cycles of f in various ways. I suspect that these graphs hold information which may be of interest to those who study iterations of quadratic rational functions. For example: if f has an attracting cycle of order n, there are connected domains in the complex plane where the values of G lie in the basin of convergence of f^n corresponding to the points in the n-cycle. Sometimes these domains are all bounded sets, and sometimes there are unbounded sets among them. Some f have attracting cycles of both sorts. I do not know whether this behavior of G reflects significant differences in the way points converge under iteration of f to the fixed cycles of f. I will show several examples, and demonstrate the program I use to explore them. This program is available as a free download. (Received August 04, 2014)

1106-30-184 **Dima Khavinson*** (dkhavins@usf.edu), Department of Mathematics, University of South Florida, Tampa, FL 33620. *"Isoperimetric Sandwiches" in Function-Theoretic Operator Theory.* Preliminary report.

I shall discuss several classical isoperimetric inequalities (e.g., volume vs. surface area of the boundary, harmonic radius vs. volume radius, torsional rigidity of a domain vs. area) as corollaries of so-called "isoperimetric sandwiches" that involve seemingly unrelated function-theoretic and operator-theoretic quantities: analytic and harmonic contents (best approximations), norms of self-commutators of some simple subnormal operators , etc. I will illustrate this theme with few recent examples and then focus on several attractive open problems. (Received August 06, 2014)

1106-30-483 **Wali Muhammad Shah*** (wmshah@yahoo.co.in), Jammu and Kashmir Institute of Mathematical, Sciences,Amar Singh College Campus,Srinagar, Kashmir,India, India.
Frontiers of Bernstien type Inequalities for Polynomials and Rational Functions.

Let $P(z)$ be a polynomial of degree n, then

$$\max_{|z|=1} |P'(z)| \leq n \max_{|z|=1} |P(z)|.$$

This is a well-known result due to S. Bernstein [Q. I. Rahman and G. Schmeisser, Analytic Theory of Polynomials, Oxford Science Publications, (2002), P.508].In the proof of this inequality Bernstein applied the Gauss-Lucas theorem and the central idea is that if a polynomial $P(z)$ has all its zeros in the unit disk,then so does the derivative $P'(z)$. There are operators other than the differentiation for which this is true and Polar derivative with respect to a point outside the unit disk is one such operator. There are many others and just as interesting. In this talk besides the characterization of some operators, we shall discuss Bernstein type inequalities for rational functions and find their connections with the polynomial inequalities preserved by these operators. (Received August 30, 2014)

1106-30-484 **Abdul Liman Wani*** (abliman@rediffmail.com), Department of Mathematics, NIT Srinagar, Kashmir, Srinagar, Kashmir 190006, India. *On Some Inequalities Concerning the Polar Derivative of a Polynomial.*

In this paper ,we establish some inequalities concerning to polar derivatives of polynomial having all its zeros inside or outside a unit circle and thereby present some compact generalizations of certain well known polynomial inequalities.

(Received August 30, 2014)

1106-30-498 **Samaneh Gholizadeh Hamidi*** (s.hamidi_61@yahoo.com), Institute of Mathematical Sciences, University of Malaya, 50603 Kuala Lumpur, Malaysia, 50603 Kuala Lumpur, Malaysia, and **Jay M Jahangiri** (jjahangi@kent.edu), Department of Mathematical Sciences, Kent State University, 14111 Claridon, Troy Road, Burton, Ohio 44021-9500, U.S.A., Burton, OH 44021-9500. *Faber polynomial coefficients of classes of m-fold symmetric bi-univalent functions.* Preliminary report.

Each function $f(z) = z+\sum_{n=2}^{\infty} a_n z^n$ in $\mathcal{S}$ analytic and univalent in the open unit disk $\mathbb{D} := \{z : |z| < 1\}$ generates a sequence of m-fold symmetry functions $g_m(z) = \sqrt[m]{f(z^m)} = z + \sum_{n=2}^{\infty} b_{mn-1} z^{mn-1}$ in $\mathcal{S}$; $(m = 1, 2, 3, \ldots)$. Conversely, every $g_m \in \mathcal{S}$ is the $m^{th} - root$ transform of some function $f \in \mathcal{S}$. Each $f \in \mathcal{S}$ has an inverse f^{-1} satisfying $f^{-1}(f(z)) = z$; $(|z| < 1)$ and $f(f^{-1}(w)) = w$; $(|w| < r_0(f),\ r_0(f) \geq 1/4)$. The Koebe function $k(z) = z/(1-z)^2$ and its inverse map $K(w) = w + \sum_{n=2}^{\infty} ((2n)!/[n!(n+1)!])\, w^n$ are prominent members of inverse univalent functions. Very little is known about the classes of m-fold symmetric bi-univalent functions. An analytic function is said to be bi-univalent in $\mathbb{D}$ if both the function and its inverse map are univalent in $\mathbb{D}$. We use the Faber polynomial expansion to investigate the unpredictable behavior of the early coefficients of classes of m-fold symmetric bi-univalent functions and also give an estimates for the general coefficients of such functions subject to a given gap series condition. (Received August 31, 2014)

1106-30-1090 **Alexander (Oleksandr) V Tovstolis*** (atovstolis@math.okstate.edu), Oklahoma State University, Departmant of Mathematics, 401 Mathematical Sciences, Stillwater, OK 74078. *On the Mahler Measure of the Hadamard Product of Polynomials.*

The Hadamard Product of two polynomials $P(z) = \sum_{k=0}^{n} p_k z^k$ and $Q(z) = \sum_{k=0}^{n} q_k z^k$ is given by $(P * Q)(z) = \sum_{k=0}^{n} p_k q_k z^k$.

For Hardy spaces H^p $(0 < p \leq \infty)$ and the space of Mahler measure, H^0, in the unit disk $\mathbb{D}$ of the complex plane, we obtained the following estimate:

$$\|P * Q\|_{H^p} \leq \|\Theta_n\|_{H^0} \|P\|_{H^0} \|Q\|_{H^p}, \quad 0 \leq p \leq \infty, \tag{1}$$

where

$$\Theta_n(z) := \sum_{k=0}^{n} \binom{n}{k}^2 z^k.$$

For $p = 0$, equality in (1) is achievable, e.g., taking $P(z) = Q(z) = (1 + z)^n$.

Furthermore,

$$\lim_{n\to\infty} \|\Theta_n\|_{H^0}^{1/n} = \exp\left(\frac{4G}{\pi}\right) \approx 3.20991230072\cdots,$$

where $G = \sum_{m=0}^{\infty} \frac{(-1)^m}{(2m+1)^2}$ is Catalan's constant.

As an illustration of the method, estimates for the Mahler measure and the H^p-pre-norm of the odd and even parts of a polynomial were derived. (Received September 10, 2014)

1106-30-1345 **George Csordas** and **Tamas Forgacs*** (tforgacs@csufresno.edu), 5245 N. Backer Ave, M/S PB108, Department of Mathematics, California State University, Fresno, Fresno, CA 93740-8001. *Classical multiplier sequences: a special class, continuous transformations, and connections to special functions.* Preliminary report.

This talk considers a special class of classical multiplier sequences, which are interpolated by either logarithmic functions, or 'power' functions of the form $f(z) = \dfrac{(z+a)^s}{\Gamma(z+1)}$, $(a, s \in \mathbb{R})$. After presenting some results and problems which remain open, we discuss the notion of continuous transformation of a classical multiplier sequence (in one or more parameters), and highlight some unexpected, but beautiful connections between classical multiplier sequences, Laguerre polynomials, and hypergeometric functions. (Received September 17, 2014)

1106-30-1595 **Michael J Miller*** (millermj@lemoyne.edu), Dept of Mathematics, Le Moyne College, Syracuse, NY 13214. *A local extremum with multiple roots for the Sendov conjecture.* Preliminary report.

Let $S(n)$ be the set of all polynomials of degree n with all roots in the unit disk, and define $d(P)$ to be the maximum of the distances from each of the roots of a polynomial P to that root's nearest critical point. In this notation, Sendov's conjecture asserts that $d(P) \leq 1$ for every $P \in S(n)$.

Define $P \in S(n)$ to be *locally extremal* if $d(P) \geq d(Q)$ for all nearby $Q \in S(n)$, and note that identifying all locally extremal polynomials would settle the Sendov conjecture.

Previously constructed locally extremal polynomials have all had simple roots. In this paper, we construct a locally extremal polynomial of degree 10 with multiple roots. (Received September 14, 2014)

1106-30-1702 **Lisa Lorentzen*** (lisa@math.ntnu.no), Department of mathematical sciences, NTNU, N-7491 Trondheim, Norway. *Convergence of random continued fractions.*

An old dream of mine has been to prove that almost all continued fractions $K(a_n/b_n)$ with complex elements a_n, b_n converge. It is easy to come up with divergent continued fractions, but they are rather special, such as limit periodic continued fractions $K(a_n/b_n)$ of elliptic type, or $(a_n/b_n b_{n-1}) \to \infty$ too fast. But a statement like that would naturally have to depend on the measure on the space of continued fractions. What I had in mind was some kind of sensible, natural measure.

A random continued fraction is a continued fraction where the elements (a_n, b_n) are picked randomly and independently from a probability distribution on $\mathbb{C} \times \mathbb{C}$. What are the chances that $K(a_n/b_n)$ converges? This is not quite the same question, but a connection was provided by Furstenberg already in 1963 in a different setting. Still, once on the track, it is easy to find other results which are of help, such as the Borel-Cantelli Lemma, Kolmogorov's 0-1 theorem and a lemma by L. Arnold.

With these tools it is possible to prove that under mild conditions on the measure μ on $\mathbb{C} \times \mathbb{C}$, the μ-random continued fraction converges with probability 1. It is a miracle that continued fractions are so cooperative... (Received September 15, 2014)

1106-30-1746 **Alberto A. Condori*** (acondori@fgcu.edu), 10501 FGCU Blvd. South, Fort Myers, FL 33969. *Cyclicity in Dirichlet-type spaces and Optimal Polynomials.* Preliminary report.

I will discuss recent results concerning cyclicity in Dirihlet-type spaces (of the disc and the bidisc) and optimal polynomials.

This talk is based in part on joint work with C. Bénéteau, C. Liaw, D. Seco, and A. Sola. (Received September 15, 2014)

1106-30-2022 **John A. Emanuello*** (jemanuel@math.fsu.edu), FSU Department of Mathematics, 208 Love Building, 1017 Academic Way, Tallahassee, FL 32306-4510, and **Craig A. Nolder**. *The Conformal Groups of The Quaternions and Split-Quaternions.*

We examine the quaternions and split-quaternions as higher dimensional analogues of the complex plane. In a natural way, these may be realized as the semi-Riemannian manifolds $\mathbb{R}^{4,0}$ and $\mathbb{R}^{2,2}$. This allows for a conformal geometry to be defined. We study the conformal groups and show that they may be realized as 2×2 matrices with entires in the corresponding algebra. (Received September 15, 2014)

1106-30-2080 **Khim R Shrestha***, 215 Carnegie Building, Syracuse University, Syracuse, NY 13244. *Intersection of Poletsky-Stessin Hardy Spaces on Polydisk.* Preliminary report.

Let u be a continuous negative plurisubharmonic exhaustion function on $\mathbb{D}^n$ with finite Monge-Ampère mass. The Poletsky–Stessin Hardy space $H^p_u(\mathbb{D}^n)$ consists of all holomorphic functions on $\mathbb{D}^n$ satisfying the growth condition

$$\overline{\lim_{r\to 0^-}} \int_{S_{u,r}} |f|^p \, d\mu_{u,r} < \infty$$

It is known that these spaces are contained in the classical Hardy space $H^p(\mathbb{D}^n)$ and if the exhaustion u is such that $(dd^c u)^n$ is compactly supported then $H^p_u(\mathbb{D}^n) = H^p(\mathbb{D}^n)$. But in general these spaces are different. For instance if u and v are two exhaustions such that $u \le v$ near the boundary $\partial\mathbb{D}^n$ then $H^p_u(\mathbb{D}^n) \subset H^p_v(\mathbb{D}^n)$. So for the different exhaustions chances are that we get different Poletsky–Stessin Hardy spaces. In fact, there are abundance of Poletsky–Stessin Hardy spaces on $\mathbb{D}^n$. In this presentation I will talk about the intersection of Poletsky–Stessin Hardy spaces on $\mathbb{D}^n$ over all exhaustion functions. (Received September 15, 2014)

1106-30-2137 **Gabriel T Prajitura*** (gprajitu@brockport.edu), 350 New Campus Drive, Brockport, NY 14420, and **Liangying Jiang** and **Ruhan Zhao**. *Koremblum constant in Bloch spaces.* Preliminary report.

We will discuss if and when pointwise inequality implies norm inequality for functions in the Bloch spaces. (Received September 15, 2014)

1106-30-2210 **Joseph Bak** and **Strashimir G Popvassilev*** (spopvassilev@ccny.cuny.edu), Dept Math, The City College of New York, NAC 8/133, Convent Ave at 138th Street, New York, NY 10031. *The Evolution of Cauchy's Closed Curve Theorem and Newman's Simple Proof.* Preliminary report.

We examine the development of Cauchy's Closed Curve Theorem, including the early contributions of Clairaut, d'Alembert, Cauchy himself, Goursat, and Pringsheim, as well as more recent approaches due to Ahlfors, Rudin and others. A particularly simple proof was given by D.J. Newman, utilizing his original definition of a simply-connected region in the (complex) plane. We show that this definition is equivalent to the other, more familiar definitions of simple-connectedness so that Newman's approach offers an alternative and very elegant proof of the general result. (Received September 16, 2014)

1106-30-2844 **Tariq M Qazi***, Department of Mathematics and Economics, Petersburg, VA 23806. *SOME INEQUALITIES FOR THE GROWTH OF SELF-RECIPROCAL POLYNOMIALS.*

In this talk, we will discuss a property of a self reciprocal polynomials and use it to obtain few inequalities for the growth of such polynomial. (Received September 16, 2014)

1106-30-2930 **Mohammed A. Qazi*** (qazima@aol.com), Dept of Mathematics, Tuskegee, AL 36088. *An L^p Inequality for Polynomials.*

Let $\mathcal{P}_n$ be the class of all polynomials of degree at most n, and let $\mathcal{M}_p(g\,;\rho)$ denote the L^p mean of g on the circle of radius ρ centered at the origin. We specify a number $\rho^* \in (0\,,1)$, depending on n and k, such that for any $f \in \mathcal{P}_n$, the ratio $\mathcal{M}_p(f^{(k)}\,;\rho)/\mathcal{M}_p(f\,;1)$ is maximized by $f(z) := z^n$ for all $\rho \in [\rho^*\,,\infty)$ and $p \ge 1$. Here, $f^{(k)}$ denotes the k-th derivative of f. The interest of the result lies in the fact that ρ^* is strictly less than 1. (Received September 17, 2014)

31 ► Potential theory

1106-31-107 **Hyunchul Park*** (hpark02@wm.edu), Department of Mathematics, College of William & Mary P.O. Box 8795, Williamsburg, VA 23187, and **Renming Song**. *Harmonic measure for subordinate Brownian motions with Gaussian components on $C^{1,1}$ open sets and its applications.*

In this paper we investigate the harmonic measure $\mathbb{P}_x\left(X_{\tau_D} \in \cdot\right)$ for a large class of subordinate Brownian motions with Gaussian components on bounded $C^{1,1}$ open sets D in $\mathbb{R}^d$, $d \ge 2$. Unlike Brownian motions or $\alpha-$stable processes the harmonic measure is supported on ∂D as well as $\bar{D}^c$ and we will show that each part can be represented as an integral against the Martin kernel $M_D(x,z)$, $x \in D$, $z \in \partial D$ and the Poisson kernel $P_D(x,z)$, $x \in D$, $z \in \mathbb{R}^d \setminus \overline{D}$, respectively. (Received July 17, 2014)

1106-31-2625 **Dewey R Estep*** (estepdy@mail.uc.edu), 344 Shiloh St Apt 202, Cincinnati, OH 45220, and **Nageswari Shanmugalingam** (shanmun@uc.edu). *Solving the Dirichlet problem for Bounded Domains in Metric Measure Spaces with Prime End Boundary data.*

First introduced in the complex plane by Caratheodory, Prime Ends provide a way to define the boundary of a bounded domain such that its closure retains many properties intrinsic to the structure of the domain itself rather than its ambient space. For example, the Prime End closure of the Slit Disk in $\mathbb{C}$ retains the structure imposed by the 'slit,' while the normal metric closure ignores it. Using the definition given by Adamowicz, Bjorn, Bjorn and Shanmugalingam, we may speak of Prime Ends in more general metric spaces. Here we define and study the Dirichlet Problem with Prime End Boundary data on bounded domains, showing that under certain assumptions we may construct solutions using the Perron Method. (Received September 16, 2014)

32 ► Several complex variables and analytic spaces

1106-32-188 **Evan Castle** (esca225@g.uky.edu), **Debraj Chakrabarti** (chakr2d@cmich.edu) and **David Gunderman*** (djgunder15@wabash.edu), 11650 E Sycamore St., Zionsville, IN 46077, and **Ellen Lehet** (lehetev195@potsdam.edu). *Hölder estimates for Cauchy-Type Integrals in several variables.*

We prove estimates in Hölder spaces for some Cauchy-type integral operators representing holomorphic functions in Cartesian and symmetric products of planar domains. For example, we consider the following n-dimensional analog of the Cauchy Integral:

$$\mathcal{B}_n\phi(z_1,\dots,z_n)=\frac{1}{2\pi i}\int_\Gamma \frac{\phi(t)dt}{(t-z_1)(t-z_2)\dots(t-z_n)},$$

where the smooth curve Γ is the boundary of a domain U in the plane, ϕ is continuous on Γ and $\mathcal{B}_n\phi$ is a function of n complex variables. We prove the following result: *For $k \geq 0$ and $0<\alpha<1$, the map $\mathcal{B}_n$ is continuous from $\mathcal{C}^{k+n-1,\alpha}(\Gamma)$ to $\mathcal{C}^{k,\alpha}(U^n)$.* Though the kernel of the integral transform is analytic, the mapping $\mathcal{B}_n$ displays a loss of smoothness. (Received August 06, 2014)

1106-32-270 **Alan A. Sola*** (a.sola@statslab.cam.ac.uk), DPMMS, Wilberforce Road, Cambridge, CB3 0WB, United Kingdom. *Capacity and cyclicity in Dirichlet spaces in several variables.*

I will discuss how appropriate notions of capacity of sets in the Shilov boundary relate to cyclicity, with respect to multiplication by the coordinate functions, of vectors in Dirichlet spaces of polydisks and balls.

The talk will be based in part on joint work with Bénéteau, Knese, Kosiński, Liaw, and Seco. (Received August 18, 2014)

1106-32-835 **Turgay Bayraktar*** (tbayrakt@syr.edu), 215 Carnegie Building, Syracuse, NY 13244-1150. *Constraints on automorphism groups of higher dimensional manifolds.*

It is known that a compact complex surface admits a holomorphic automorphism with positive topological entropy if it is Kaehler and obtained from the projective plane, torus, K3 surface or Enriques surface by a finite sequence of point blow-ups. In this talk, I will discuss some natural constraints on the size of the automorphism groups of higher dimensional compact complex manifolds. The talk will be based on the joint work with Serge Cantat. (Received September 07, 2014)

1106-32-975 **C. Beneteau*** (cbenetea@usf.edu), **G. Knese**, **L. Kosinski**, **C. Liaw**, **D. Seco** and **A. Sola**. *Cyclic polynomials in two variables.*

In this talk, I will give a characterization of polynomials in two complex variables that are cyclic with respect to the coordinate shifts acting on Dirichlet-type spaces in the bidisk, which include the Hardy space and the Dirichlet space of the bidisk. The cyclicity of a polynomial depends on both the size and nature of the zero set of the polynomial on the distinguished boundary. The techniques in the proof come from real analytic function theory, determinantal representations for stable polynomials, and harmonic analysis on curves. This talk is based on a paper that is joint with Greg Knese, Lukasz Kosinski, Conni Liaw, Daniel Seco, and Alan Sola. (Received September 09, 2014)

1106-32-977 **James Sunkes*** (sunkes@math.utk.edu). *Hankel Forms on the Drury-Arveson Space.*

The Drury-Arveson space has seen a healthy amount of research in the past few years, because of its connection to ideas from operator theory and because of its realization as a Besov-Sobolev space. In this talk, we will discuss Hankel forms for the Drury-Arveson space and give partial results towards their characterization. (Received September 09, 2014)

1106-32-1505 **Ozcan Yazici*** (oyazici@syr.edu). *Extension of plurisubharmonic functions with logarithmic growth.*

Let X be an algebraic subvariety of $\mathbb{C}^n$ and $\overline{X}$ be its closure in $\mathbb{P}^n$. Coman-Guedj-Zeriahi proved that any plurisubharmonic function with logarithmic growth on X extends to a plurisubharmonic function with logarithmic growth on $\mathbb{C}^n$ when the germs $(\overline{X},a)$ in $\mathbb{P}^n$ are irreducible for all $a\in\overline{X}\setminus X$. In this talk we will consider X for which the germ $(\overline{X},a)$ is reducible for some $a\in\overline{X}\setminus X$ and we give a necessary and sufficient condition for

X so that any plurisubharmonic function with logarithmic growth on X extends to a plurisubharmonic function with logarithmic growth on $\mathbb{C}^n$. (Received September 13, 2014)

1106-32-2255 **Paul Reschke*** (preschke@umich.edu), Department of Mathematics, University of Michigan, 530 Church St, 2076 East Hall, Ann Arbor, MI 48109. *Embedding Complex Surface Automorphisms Into Birational Self-Maps of Rational Varieties.*

It is a well-known result in algebraic geometry (due essentially to Chow) that an endomorphism of a complex projective variety can always be realized as the restriction of some rational self-map of a projective space. Fakhruddin explained how to construct a rational self-map of this sort in the special case where the endomorphism is polarized–and showed that the rational self-map is actually itself an endomorphism. I will explain how to use some of Fakhruddin's ideas to construct rational self-maps of rational varieties which restrict to certain automorphisms of complex projective surfaces–and I will show that these rational self-maps are actually birational. I will then explain how the construction of these rational self-maps can be useful in understanding certain families of K3 surface automorphisms. (Received September 16, 2014)

1106-32-2634 **Brendon Kerr Ballenger*** (bballeng@math.fsu.edu), 208 Love Building, 1017 Academic Way, Tallahassee, FL 32306-4510, and **Craig A Nolder**. *Conjugate Harmonic Components of Monogenic Functions.*

We study the conjugate harmonic components of monogenic functions, i.e. functions in the kernel of the Cauchy Riemann Operator, and we show that a Clifford-valued function can be decomposed into even and odd parts. We explore the relationships between these parts in terms of monogenicity, paramonogenicity, and non-tangential limits. Lastly, we prove a monogenic Riesz theorem. (Received September 16, 2014)

1106-32-2648 **Sara W. Lapan*** (slapan@math.northwestern.edu). *Domain of attraction along an apparent direction for holomorphic maps tangent to the identity.*

Given f, a germ of a holomorphic self-map of $\mathbb{C}^m$ that fixes a point p, how do points near p behave under iteration by f? More specifically, when does there exist a domain whose points are attracted to p under iteration by f and, if such a domain exists, what can be said about how the points converge to p? In this talk, we will consider these questions for such maps f that are tangent to the identity at p (i.e., $df_p = \mathrm{Id}$). The Leau-Fatou flower theorem, which describes the existence of domains of attraction in dimension one, serves as inspiration for this study in higher dimensions. We will discuss what is known in dimension two, focusing on new results regarding the existence of a domain of attraction whose points converge along an apparent characteristic direction. (Received September 16, 2014)

1106-32-2734 **Diana Thomson La Corte*** (dlacorte@smwc.edu), Saint Mary-of-the-Woods College, Department of Sciences and Mathematics, 1 St Mary of Woods Coll, St Mary of the Woods, IN 47876. *An Algebraic Approach to the Initial Weight Problem for Complex-Valued Polynomial Neural Networks.* Preliminary report.

The application of Newton's method to the backpropagation training algorithm for complex-valued neural networks (CVNNs) faces distinct difficulties. In particular, the choice of the initial iterates when applying Newton's method to the minimization of any function on a complex domain is a well-known problem. When Newton's method is applied to training CVNNs, this becomes the problem of choosing initial weights that guarantee minimization of the error function. We propose the use of polynomials as activation functions for CVNNs, thus allowing us to take an algebraic approach to the initial weight problem. In this talk, we investigate the application of an algebraic root-finding technique to the case of polynomial CVNNs to develop a theoretical algorithm for the location of initial weight vectors that will guarantee successful training. (Received September 16, 2014)

33 ► Special functions

1106-33-100 **Xiaolong Han*** (xiaolong.han@anu.edu.au), Department of Mathematics, Australian National University, Canberra, ACT 0200, Australia. *Spherical harmonics with maximal norm growth.*

Sogge's Lp estimates bound the Lp norms of normalized eigenfunctions on smooth and compact manifolds. They are also sharp on the sphere, with maximizers as Gaussian beams for small p and zonal harmonics for large p. In this talk, we investigate the density of these maximizers in the orthonormal eigenfunction basis, and construct a positive density subsequence of orthonormal spherical harmonics which achieves the maximal Lp norm growth for all small p. This gives an example of a Riemannian surface supporting such subsequence of eigenfunctions. Furthermore, we provide an explicit lower bound on the density in this example. (Received July 16, 2014)

1106-33-340 **Arcadii Z. Grinshpan*** (agrinshp@usf.edu). *Extremal properties of weighted convolutions.*

Sharp inequalities for weighted convolutions [1] can be presented and used in various equivalent forms. The most elegant of them are the semi-norm inequality for power series and inequality for expectations of interrelated random variables. The analysis of their extreme cases which employs the convolution properties of Bernstein polynomials will be discussed. Some examples and applications involving special functions, differential operators, integral equations, and a probabilistic interpretation will be given.

[1] A.Z. Grinshpan, Weighted inequalities and negative binomials, Advances in Applied Mathematics 45 (2010), 564-606. (Received August 23, 2014)

1106-33-482 **Saroj Aryal*** (saroj.aryal@msubillings.edu), Department of Mathematics, Montana State University Billings, Billings, MT 59101, and **Farhad Jafari** (fjafari@uwyo.edu), Department of Mathematics, University of Wyoming, Laramie, WY 82071. *Effects of Perturbation of Terms of S-fractions in the Corresponding Stieltjes Transforms.* Preliminary report.

Stieltjes transform of a measure plays an important role in the study of moment problems. We study how perturbation of terms of an S-fraction affects the measure associated with the corresponding Stieltjes transform. We further investigate the effects of perturbation of Stieltjes moments. (Received August 30, 2014)

1106-33-734 **Daniel P Schultz***, dps23@psu.edu. *cubic modular equations in two variables.*

By adding certain equianharmonic elliptic sigma functions to the q - series coefficients of the Borwein cubic theta functions, an interesting set of six two-variable theta functions may be derived. These theta functions invert the $F_1\left(\frac{1}{3};\frac{1}{3};\frac{1}{3};1|x,y\right)$ case of Appell's hypergeometric function and satisfy several identities akin to those satisfied by the Borwein cubic theta functions. Previous results of K. Koike and H. Shiga are extented and put into the context of modular equations, resulting in a simpler derivation of their results and well as several new modular equations for Picard modular forms. (Received September 05, 2014)

1106-33-778 **Mohan V G K Rudravarapu*** (mohanrudravarapu@gmail.com), Flat No-408, MVV ESTATES, CHINA WALTAIR, NEAR KOTAK SCHOOL, VISAKHAPATNAM, India, and **Pankaj Srivastava** (pankajs23@redimail.com), Prof Pankaj Srivastava, Department of Mathematics, MNNNIT, UP, INDIA, ALLAHABAD, India. *Some q-Continued fractions and their connections with Lambert series and mock theta functions.*

Mock theta function is last gift to Mathematical world by S.Ramanujan, that he quoted in his last letter to G.H. Hardy on January 12,1920. Lambert series is a well known series used by Ramanujan to prove many of his identities. Following Ramanujan, many mathematicians like George Andrews and B. C. Berndt also used these series to prove many of Ramanujan identities. In the present work, by making use of Andrews and Hickerson identities, we have established certain new q-continued fractions for the ratio of Lambert series and also for the ratio of combination of mock theta function of order six.

2010 Mathematics Subject Classification : 33D15, 33E99.
Keywords: Lambert series, Continued fractions, mock theta function.
(Received September 06, 2014)

1106-33-1568 **Horst Alzer** (h.alzer@gmx.de), Morsbacher Str. 10, 51545 Waldbröl, Germany, and **Kendall Richards*** (richards@southwestern.edu), Southwestern University, Mathematics and Comp. Sci. Department, 1001 E. University Ave., Georgetown, TX 78626. *On the Modulus of the Grötzsch Ring.* Preliminary report.

We study monotonicity, concavity and convexity properties of the function

$$G_r(\alpha)=\frac{\mu(r^\alpha)}{\alpha}\quad(0<r<1;\ \alpha>0),$$

where μ denotes the modulus of the Grötzsch ring. Moreover, we apply our results to obtain various sharp functional inequalities. (Received September 14, 2014)

34 ► Ordinary differential equations

1106-34-84 **Johnny Henderson*** (johnny_henderson@baylor.edu), Department of Mathematics, Baylor University, Waco, TX 76798-7328, and **Nickolai Kosmatov** (nxkosmatov@ualr.edu), Department of Mathematics and Statistics, University of Arkansas at Little Rock, Little Rock, AR 72204-1099. *Eigenvalue comparison for fractional boundary value problems with the Caputo derivative.*

We apply the theory for u_0-positive operators to obtain eigenvalue comparison results for a fractional boundary value problem with the Caputo derivative. (Received July 06, 2014)

1106-34-99 **Toka Diagana*** (tokadiag@gmail.com), Department of Mathematics, Howard University, 2441 6th Street NW, Washington, DC 20059. *Existence Results for Some Classes of Integro-differential Equations.* Preliminary report.

This talk is devoted to some new existence results for some integro-differential equations in abstract spaces. Various techniques will be utilized to establish these existence results. Next, we present some applications. (Received July 16, 2014)

1106-34-151 **Ling Xue*** (lxue2@tulane.edu), Department of Mathematics, 6823 St Charles Ave, New Orleans, LA 70118, and **Carrie Manore**, **Panpim Thongsripong**, **Soodeh Azizi** and **Mac Hyman**. *Two-Sex Mosquito Model for the Spread of Wolbachia.* Preliminary report.

Wolbachia are maternally transmitted endosymbiotic bacteria that have the potential of reducing the ability of mosquitoes to transmit Dengue. To understand how *Wolbachia* can invade and sustain in mosquito populations, we developed an ordinary differential equation compartmental model. The model incorporates aquatic stage, female, and male adult mosquitoes taking into account fitness change and cytoplasmic incompatibility. Increasing the number of initial infections at endemic equilibrium leads to complete infection equilibrium and decreasing the number of initial infections at endemic equilibrium leads to disease free equilibrium, resulting in an interesting backward bifurcation. The thresholds for the number of *Wolbachia* infected mosquitoes needed to be released to establish *Wolbachia* in mosquitoes after implementing mosquito control strategies were compared. Killing uninfected female mosquitoes frequently requires the least number of *Wolbachia*-infected mosquitoes for *Wolbachia* to establish in mosquito population. Mathematical analysis and numerical simulation results help us understand factors that determine invasion and establishment of *Wolbachia* in mosquito populations. (Received July 29, 2014)

1106-34-172 **John R. Graef** (john-graef@utc.edu), TN , and **Xueyan Sherry Liu*** (xueyan-liu@utc.edu), 615 McCallie Avenue, Dept. 6956, Chattanooga, TN 37343. *Existence of Positive Solutions of Fractional Boundary Value Problems Involving Bounded Linear Operators.*

This paper is concerned with boundary value problems for nonlinear fractional differential equations with a nonlinear term involving a bounded linear operator and satisfying boundary conditions containing a bounded linear functional. The explicit expression for an equivalent integral operator for the BVP is given. A recent fixed point theorem is used to obtain the existence of at least three positive solutions. The paper also provides an example as an application of the existence theorem. (Received August 04, 2014)

1106-34-198 **Xuewei Jiang*** (xuewei_jiang@baylor.edu), Baylor University, Waco, TX 76798. *Differentiation with Respect to Parameters of Solutions of Nonlocal Boundary Value Problems for Difference Equations.*

For the nth order difference equation, $\Delta^n u = f(t, u, \Delta u, ..., \Delta^{n-1}u, \lambda)$, the solution of the boundary value problem satisfying $\Delta^{i-1}u(t_0) = A_i, 1 \leq i \leq n-1$, and $u(t_1) - \sum_{j=1}^{m} a_j u(\tau_j) = A_n$, where $t_0, \tau_1, \ldots, \tau_m, t_1 \in \mathbb{Z}$, $t_0 < \cdots < t_0 + n - 1 < \tau_1 < \cdots < \tau_m < t_1$, and $a_1, \ldots, a_m, A_1, \ldots, A_n \in \mathbb{R}$, is differentiated with respect to the parameter λ. This talk will discuss the new theorem we proved that $\frac{\partial u}{\partial \lambda}$ exists on $[t_0, +\infty)_{\mathbb{Z}}$, and $w(t) := \frac{\partial u}{\partial \lambda}(t)$ is the solution of the nonhomogeneous linear equation, $\Delta^n z = \sum_{i=1}^{n} \frac{\partial f}{\partial s_i}(t, u(t), \ldots, \Delta^{n-1}u(t), \lambda)\Delta^{i-1}z + \frac{\partial f}{\partial \lambda}(t, u(t), \ldots, \Delta^{n-1}u(t), \lambda)$, along $u(t)$ and satisfies $\Delta^{i-1}w(t_0) = 0,\ 1 \leq i \leq n-1$, and $w(t_1) - \sum_{j=1}^{m} a_j w(\tau_j) = 0$. (Received August 08, 2014)

1106-34-315 **Yun Kang*** (yun.kang@asu.edu), **Marisabel Rodriguez Rodriguez** (yun.kang@asu.edu) and **Stephen Evilsizor** (yun.kang@asu.edu). *Ecological and evolutionary dynamics of a two-stage model with egg cannibalism for social insects.* Preliminary report.

Cannibalistic interactions between different developmental stages in a population are prevalent among many groups of animals and social insects. Cannibalism plays an important role in the population outcomes and represents an adaptive strategy in which parents consume some offspring to increase their current and/or future reproductive success. To understand how egg cannibalism affects ecological dynamics and evolutionary outcomes, we propose a simple two stage ecological and evolutionary model by using the frame work of evolutionary game theory approach. Our study shows that:

1. When the environment is harsh, egg cannibalism can prevent extinction in the absence of the evolution. Moreover, large egg cannibalism can lead to a forward transcritical bifurcation at which is characterized by the emergence of a globally stable interior equilibrium while small egg cannibalism can lead to a backward subcritical bifurcation which can lead to strong Allee effects.
2. When the environment is harsh, evolution can prevent extinction.
3. Evolution may decrease or increase the fitness of the colony by decreasing or increasing the total population size.
4. The trait function is very important since it can affect the permanence of the system. (Received August 21, 2014)

1106-34-391 **John R Graef*** (john-graef@utc.edu), Department of Mathematics, The University of Tennessee at Chattanooga, Chattanooga, TN 37403, and **Shapour Heidarkhani** and **Lingju Kong**. *Infinitely Many Periodic Solutions to Perturbed Second-order Impulsive Hamiltonian Systems.*

The authors investigate the existence of infinitely many periodic solutions to the perturbed impulsive Hamiltonian system with periodic boundary conditions

$$\begin{cases} -\ddot{u}(t) + A(t)u(t) = \lambda\nabla F(t,u(t)) + \mu\nabla G(t,u(t)) + \nabla H(u(t)), \quad a.e.\ t \in [0,T], \\ \Delta(\dot{u}_i(t_j)) = I_{ij}(u_i(t_j)), \qquad i = 1,2,\ldots,N,\ j = 1,2,\ldots,p, \\ u(0) - u(T) = \dot{u}(0) - \dot{u}(T) = 0, \end{cases} \tag{1}$$

where $u = (u_1, u_2, \ldots, u_N)$, $N \geq 1$, $p > 1$, $T > 0$, $\lambda > 0$ and $\mu \geq 0$ are parameters, $0 = t_0 < t_1 < \cdots < t_p < t_{p+1} = T$, A is an $N \times N$ symmetric matrix, and $\Delta(\dot{u}_i(t_j)) = \dot{u}_i(t_j^+) - \dot{u}_i(t_j^-) = \lim_{t\to t_j^+} \dot{u}_i(t) - \lim_{t\to t_j^-} \dot{u}_i(t)$. (Received August 26, 2014)

1106-34-714 **Zhivko S. Athanassov*** (zhivko@math.bas.bg), G. Bonchev Str. 8, 1113 Sofia, Bulgaria. *Some Properties of Solutions of Differential Systems Under Caratheodory Conditions.* Preliminary report.

Thr existence, uniqueness, differential inequalities, integral funnels and stability of Caratheodory solutions of systems of first order nonlinear ordinary differential equations are discussed. (Received September 05, 2014)

1106-34-773 **J. Diego Ramirez*** (diego.ramirez@lamar.edu), Department of Mathematics, 200 Lucas Building, P.O. Box 10047, Beaumont, TX 77710. *Generalized Monotone Method for Caputo Fractional Integro-Differential Equations of order q, $0 < q < 1$.*

In this work, we consider a first order fractional integro-differential equation with Caputo derivative of order q, $0 < q < 1$, and initial condition. In our case the forcing function is the sum of an increasing and decreasing function.

We define lower and upper solutions and will prove the existence of coupled minimal and maximal solutions by using a generalized monotone iterative technique where the iterates are solutions of linear Caputo fractional integro-differential equations with initial condition. (Received September 06, 2014)

1106-34-867 **Pietro-Luciano Buono*** (luciano.buono@uoit.ca), Faculty of Science, 2000 Simcoe Street North, Oshawa, Ontario L1H 7K4, Canada, **Daniel C. Offin**, Department of Mathematics and Statistics, Queen's University, Kingston, Ontario , Canada, **Mark Lewis**, Department of Mathematics and Statistics, Queen's University, Kingston, Ontario , Canada, and **Mitchell Kovacic**, Department of Mathematics, Simon Fraser University, Burnaby, BC , Canada. *Stability analysis and bifurcations of the Hip-Hop orbit and beyond.*

I will begin by discussing recent results obtained with M. Lewis, D. Offin (Queen's) and M. Kovacic (UOIT) about the Hip-Hop orbit of the Newtonian 2N-body problem. The Hip-Hop orbit (in reduced space) is a periodic solution with time-reversing and spatio-temporal symmetries and in fact, we have shown that it is a brake orbit. I will also present the analytical proof of linear instability of the Hip-Hop orbit using Maslov index methods. I will show numerical simulations of the Hip-Hop orbit as the energy is varied which exhibits a sequence of symmetry-breaking bifurcations and discuss avenues for classifying those bifurcations. I will then present an extension of the methods used for the Hip-Hop orbit to the problem of instability of periodic orbits with spatio-temporal reversing symmetries obtained via minimization methods in Hamiltonian systems. (Received September 08, 2014)

1106-34-1124 **Roger J Thelwell*** (`thelwerj@jmu.edu`), Dept. of Math and Stats, MSC 1911, Harrisonburg, VA 22807. *Differential equations through the lens of power series.* Preliminary report.

Nonlinear Ordinary and Partial Differential Equations lie at the core of many current problems in mathematics. Recasting highly nonlinear problems as quadratic systems (a technique rediscovered and exploited by Parker and Sochacki) allows series to provide numeric and theoretic insight and intuition to these difficult problems. This talk will explore several of the many problems for which series methods are powerful tool. (Received September 10, 2014)

1106-34-1193 **Petronela Radu**, **Daniel Toundykov** and **Jeremy Trageser*** (`s-jtrages1@math.unl.edu`). *Finite time blow-up in nonlinear suspension bridge models.*

This talk will discuss a paper by P. Radu, D. Toundykov, and J. Trageser that settled a conjecture by Gazzola et al. regarding solutions to the fourth order ODE $w^{(4)} + kw'' + f(w) = 0$ which arises in models of traveling waves in suspension bridges when $k > 0$. Under suitable assumptions on the nonlinearity f and initial data, we demonstrate blow-up in finite time. The case $k \leq 0$ was first investigated by Gazzola et al. Our approach is inspired by Gazzola et al. and exhibits the oscillatory mechanism underlying the finite-time blow-up. This blow-up is non-monotone, with solutions oscillating to higher amplitudes over shrinking time intervals. In the context of bridge dynamics this phenomenon appears to be a consequence of mutually-amplifying interactions between vertical displacements and torsional oscillations. (Received September 11, 2014)

1106-34-1232 **Aghalaya S Vatsala*** (`vatsala@louisiana.edu`), Department of Mathematics, University of Louisiana at Lafayette, Lafayette, LA 70504, and **Bhuvaneswari Sambandham**, department of Mathematics, University of Louisiana at Lafayette, lafayette, LA 70504. *Some Basic Results of Caputo Fractional Differential Equations.* Preliminary report.

We have developed some basic results for fractional differential equations of order q and $2q$, when $0 < q < 1$. We have obtained a symbolic closed form of the solution for Caputo initial value problem of order q, when $0 < q < 1$, such that the classical result for $q = 1$ will be a special case. We bring in the salient difference between the oscillatory solutions obtained using the Mittag-Lefller function and the oscillatory solutions of ordinary differential equations. As a byproduct some new properties of Mittag-leffler functions are also established which is useful in applications. Several numerical results are presented. (Received September 11, 2014)

1106-34-1298 **Krishna P Pokharel*** (`kpokhar@rockets.utoledo.edu`), 1247 Oak Hill Ct Apt#267, Toledo, OH 43614, and **A Arsie**. *An isospectral flow for Hessenberg matrices and its optimality.*

In this talk, we discuss an isospectral flow (Lax flow) in the space of matrices, which deforms any given complex upper Hessenberg matrix with simple spectrum to a normal upper Hessenberg matrix. Furthermore, we prove that if the spectrum of the initial condition is contained in a line l inside the complex plane, then its omega-limit set is actually a tridiagonal normal matrix possessing a special symmetry among the off diagonal elements. Moreover, we prove that this flow provides the solution of an infinite-time horizon optimal control problem.

Some simulations results are provided to highlight some aspects of this nonlinear system. As a farther application, we show that the flow can be used to construct even dimensional tridiagonal real skew-symmetric matrices with given simple imaginary spectrum and with given sign pattern for the codiagonal elements.

The main technical aspect of the work is to prove that the omega-limit set of suitable initial conditions consists of a single point in the phase space. (Received September 11, 2014)

1106-34-1320 **Zachary Denton*** (`zdenton@ncat.edu`). *Monotone Method for Multi-Order N-Systems of Riemann-Liouville Fractional Differential Equations.* Preliminary report.

We develop the monotone method for nonlinear multi-order N-systems of Riemann-Liouville fractional differential equations. That is, a hybrid system of nonlinear equations of orders $q_1, q_2, q_3, ..., q_N$ and where $0 < q_i < 1$. In the development of this method we recall any needed existence results along with any necessary changes; including results from needed linear theory. Further we prove a comparison result paramount for the discussion of fractional multi-order inequalities that utilizes lower and upper solutions of the system. The monotone method is then developed via the construction of sequences of linear systems based on the upper and lower solutions, and are used to approximate the solution of the original nonlinear multi-order system. (Received September 12, 2014)

1106-34-1574 **M. Rahman*** (mrahman@unf.edu), Department of Mathematics & Statistics, University of North Florida, 1 UNF Drive, Jacksonville, FL 32224. *Simulation of Stochastic Differential Equations arises in mathematical neurosciences.* Preliminary report.

We develop and apply method of stochastic differential approximation to a canonical model arises in a circular process in mathematical neurosciences. We also investigate the role of noise in the circular process numerically. (Received September 14, 2014)

1106-34-1635 **David G Costa***, 4505 Maryland Parkway, Box 454020, Las Vegas, NV 89154-4020. *On Positive Solutions for a Class of Semipositone Problems with Nonlinear Boundary Conditions.*

We show existence of positive solution for a one-dimensional class of semipositone problems with nonlinear boundary conditions. Both the sublinear and superlinear situations will be considered. This is joint work sith A. Drame. (Received September 14, 2014)

1106-34-1644 **John R. Graef**, **Lingju Kong**, **Qingkai Kong** and **Min Wang*** (min-wang@utc.edu), Department of Mathematics, University of Tennessee at Chattanooga, Chattanooga, TN 37403. *A fractional boundary value problem with Dirichlet boundary conditions.*

In this paper, the authors study a nonlinear fractional boundary value problem with the Dirichlet boundary condition. The associated Green's function is derived in terms of the generalized Mittag-Leffler function, and the existence of solutions is established based on it. (Received September 14, 2014)

1106-34-1685 **Susmita Sadhu*** (susmita.sadhu@gcsu.edu) and **Saikat Chakraborty Thakur** (saikat@ucsd.edu). *Mixed mode oscillations in a singularly perturbed predator-prey-scavenger model with Holling Type II functional response.*

We consider a three-dimensional singularly perturbed predator-prey system with two predators competing directly for the same prey in a constant environment. The second predator is also a scavenger. We take into account the interference competition between the predator and the predating scavenger, and consider a Holling Type II functional response. In addition to relaxation oscillations (ROs), we observe complex dynamics such as mixed mode oscillations (MMOs), which are combinations of short amplitude oscillations (SAOs) and ROs in the system. Using the standard singular perturbation theory, the existence of stable ROs can be explained. On the other hand, MMOs in the system arise due to canard dynamics. We observe canards due to the presence of folded node singularity and also due to singular Hopf bifurcation. ROs reflect the coexistence of the three species with diversified time response. During such cycles, the population density of the prey goes through a very rapid fluctuation (with a sudden crash or an outbreak) over a fast time scale followed by a slow recovery in between. The SAOs associated with the MMOs delay the time intervals between two consecutive outbreaks/crashes in the prey population. (Received September 15, 2014)

1106-34-1825 **Kristen Abernathy*** (abernathyk@winthrop.edu). *Analysis of Steady State Solutions in an Abstract Model of Glioblastoma Multiforme under Immunotherapy Treatment.* Preliminary report.

In this presentation, we extend the work of Kogan, Forys, and Kronik (Kogan, et al. 2008) to incorporate the cancer stem cell hypothesis in the study of the treatment of Glioblastoma Multiforme by immunotherapy. We present an abstract model of nonlinear ordinary differential equations and show existence of coexistence, recurrence, and cure steady states. We analyze the stability of each steady state and present sufficiency conditions on treatment parameters to ensure a globally asymptotically stable cure state. We conclude with a biologically accurate example of our theory. (Received September 15, 2014)

1106-34-1949 **Alexander Middleton*** (middletona6@winthrop.edu). *A Nonlinear Model of Cancer Tumor Treatment with Cancer Stem Cells.*

According to the American Cancer Society, cancer is one of the leading causes of death, second only to heart disease. We present a system of nonlinear, first-order, ordinary differential equations that describes tumor growth based on healthy cell, tumor cell, and cancer stem cell populations. We include terms within our model which reflect the differing effects of chemotherapy and anti-angiogenic therapy to respective cell populations. We perform stability analysis on the equilibrium solutions to predict the long-term behavior of the cell populations. With analysis, it is shown that chemotherapy, with the co-administration of anti-angiogenic treatment, can produce three states: recurrence or persistence of cancer, and a cure state. Results are supported numerically and bifurcation diagrams are included to illustrate the different behavior of cell populations depending on the amount of treatment administered. (Received September 15, 2014)

1106-34-2073 **Hem Raj Joshi*** (joshi@xavier.edu), Department of Mathematics and CS, Xavier University, Cincinnati, OH 45242, and **Renee Margevicius**, Department of Mathematics and CS, Xavier University, Cincinnati, OH 45242. *SIR Model, Changing Behavior, and Education Campaign.*

A SIRE model will be used to evaluate the effectiveness of educational campaign on the HIV epidemic. Changed behavior as a result of the campaign will create a new SIRE model based on this campaign and divide those susceptible into four subgroups. These four susceptible classes will have different infection rates due to their differing beliefs on sexual conducts. The model is a system of ordinary differential equations and it is simulated numerically. Real world data will be compared with simulated results. (Received September 15, 2014)

1106-34-2120 **Zachary J. Abernathy*** (abernathyz@winthrop.edu). *A Mathematical Model of Treatment of Cancer Stem Cells with Immunotherapy.*

Using the work of Shelby Wilson and Doron Levy (2012), we develop a mathematical model to study the growth and responsiveness of cancerous tumors to various immunotherapy treatments. We use numerical simulations and stability analysis to predict long-term behavior of passive and aggressive tumors with a range of antigenicities. For high antigenicity aggressive tumors, we show that remission is only achieved after combination treatment with TGF-β inhibitors and a peptide vaccine. Additionally, we show that combination treatment has limited effectiveness on low antigenicity aggressive tumors and that using TGF-β inhibition or vaccine treatment alone proves generally ineffective for all tumor types considered. A key feature of our model is the identification of separate cancer stem cell and tumor cell populations. Our model predicts that even with combination treatment, failure to completely eliminate the cancer stem cell population leads to cancer recurrence. (Received September 15, 2014)

1106-34-2122 **Mihiri M. De Silva*** (mihiri.de-silva@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409, and **Sophia R. Jang** (sophia.jang@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409. *Dynamics of a Lotka-Volterra competition model with Allee effects and stocking.*

This talk is about studies asymptotic dynamics of the classical Lotka-Volterra competition model of two populations when one of the populations is subject to Allee effects. The model can have either no interior steady state, a unique interior steady state or two interior steady states. Using the tools of monotone systems, we provide global asymptotic dynamics of the model and determine competition outcomes. We derive sufficient conditions for which the model either has one, two or no interior steady states. We then incorporate stocking into the population with Allee effects important for studies of population conservation. We analyze the resulting model and provide global dynamics of the system to study the impact of stocking upon population interaction. (Received September 15, 2014)

1106-34-2571 **Ngoc Do*** (dothanh@math.tamu.edu), **Peter Kuchment** and **Frank Sottile**. *On the genericity of non-degenerate spectral edges.* Preliminary report.

It is widely believed in the mathematics and physics community that extrema of dispersion relations of generic periodic Schrödinger operators are non-degenerate. (Here by non-degeneracy we mean extrema having non-degenerate Hessian.) Unfortunately, the conjecture remains unproven. The most advanced result, obtained by F. Klopp and J. Ralston, proves that each band edge of a generic periodic Schrödinger operator is an extremal value of just a single band function. In this talk, we will present a study of the conjecture for a class of periodic differential operators on graphs. (Received September 16, 2014)

1106-34-2619 **Peter R Wolenski*** (wolenski@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *Structured discontinuous systems.*

We provide a framework to study optimal control systems with discontinuous dynamic data, but in which the state space is structured in a structured manner that allows for a complete description of the state trajectories. The framework is of a Whitney-type stratification and consists of a partition of the state space into submanifolds of various dimensions, and on each is endowed nice dynamics satisfying a structural condition. The latter is imposed to regulate the "jumping off" of a continuous trajectory from one manifold into another. A key assumption on the submanifolds is that their closures are proximally smooth and relatively wedged, concepts from nonsmooth analysis that allow for a detailed description of trajectories that originate from the boundary of the submanifold and that can penetrate into it. The main issue is to develop optimal control theory in the whole space in which a well-developed theory is available on each of the submanifolds. We offer some examples and results on weak and strong invariance, and suggest possible future research directions. (Received September 16, 2014)

1106-34-2858 **Cesar Martinez-Garza*** (cxm58@psu.edu), Penn State Berks, Tulpehocken Rd, P.O. Box 7009, Reading, PA 19610, and **William E Manigat** and **William A Keller**. *A Newton-like Method That Permits Zero Derivatives.*

In this paper, we show that the Method of Generalized Quasilinearization can be used to solve the equation $F(x)=0$, if $F(x)$ is a differentiable function on an open interval (a,b), it has a simple zero inside (a,b), and it can be decomposed as the addition of a convex and a concave functions: $F(x)=f(x)+g(x)$. The iterative scheme provided by Generalized Quasilinearization generates two sequences in terms of $f(x)$ and $g(x)$ that converge quadratically to the simple zero of $F(x)$ inside (a,b) even if $F'(x)=0$ inside the interval. We include examples of different cases, including the case when $F(x)$ cannot be naturally decomposed into the addition of convex and concave functions. (Received September 16, 2014)

1106-34-2928 **Bhagya Athukorallage*** (bhagya.athukorala@ttu.edu), Broadway and Boston, Lubbock, TX 79409-1042, and **Ram Iyer**, Broadway and Boston, Lubbock, TX 79409. *Investigation of energy losses due to contact angle hysteresis in capillary effect.*

The presence of inhomogeneities on solid substrates leads to a range of stable contact angle values for a given solid-liquid system, which is referred to as the contact angle hysteresis. It is well known that the motion of a liquid on a non-ideal surface involves dissipation of energy due to the contact angle hysteresis and the viscosity of the fluid involved. In this research, we study the former mechanism that leads to the dissipation of energy by considering two types of capillary geometries. Specifically, a liquid drop on a solid substrate and a liquid column in a capillary tube. Analytical formulas for both liquid interfaces are obtained using energy minimization approach. Here, the competing energy terms include the meniscus surface energy, adhesion energy, and volume energy due to gravitation. Our computations suggest that the hysteresis losses result due to both capillary pressure and the wet adhesion. Further, we observe that the dominant cause for hysteresis losses is the capillary pressure arising from the meniscus formation. (Received September 17, 2014)

35 ► *Partial differential equations*

1106-35-116 **Ugur G. Abdulla**, **Jian Du**, **Jonathan Goldfarb**, **Kev Johnson**, **Lauren Lanier** and **Taylor Schluter*** (taschlute@gmail.com), 150 West University Blvd., Department of Mathematical Sciences, Melbourne, FL 32901. *Analysis of Interfaces for the Nonlinear Diffusion Equation with Linear Convection.*

We investigate interface development in a Cauchy problem for the nonlinear diffusion-convection equation

$$u_t = (u^m)_{xx} + bu_x, x \in R, t > 0;\ u(x,0) = C(-x)_+^\alpha, x \in R,$$

where $m, \alpha, C > 0, b \in R$. It is proved that for the opposing direction of convection ($b > 0$) depending on m, α and C, the interface may initially expand or shrink. For slow diffusion ($m > 1$), the interface expands if $\alpha < 1/(m-1)$ and shrinks if $\alpha > 1/(m-1)$. The behavior of the interface in the case $\alpha = 1/(m-1)$ depends on the constant C. There is a critical value C_* such that the interface expands if $C > C_*$ and shrinks if $C < C_*$. We identify the region in the parameter space where a global self-similar solution exists, and the direction of the interface changes in time: a so called turning interface phenomenon is observed. For the direction of convection ($b < 0$), the interface always expands, and an explicit formula for the interface and local solution is derived in the whole parameter space. For fast diffusion $m < 1$, there is an infinite speed of propagation. In this case, the asymptotics of the solution at infinity agree with those of the diffusion equation. A WENO numerical scheme was applied to the problem and numerical results support our proved estimations. (Received July 21, 2014)

1106-35-117 **Ugur G Abdulla** (abdulla@fit.edu), Mathematical Sciences, Florida Institute of Technology, 150 W University Blvd, Melbourne, FL 32901, and **Nicholas Crispi**, **Jonathan Goldfarb** and **Daniel Kassler*** (dkassler@uchicago.edu), Dept of Mathematics, University of Chicago, 5734 South University Ave, Room 208C, Chicago, IL 60637, and **Scott Pelton-Stroud**, **Bruno Giuseppe Poggi** and **Paige Elizabeth Williams**. *On some inverse free boundary problems for second order parabolic PDEs.*

Consider the inverse Stefan problem (ISP), an inverse free boundary problem for a general second order linear parabolic PDE. The problem arises when considering phase transition processes with unknown temperature function and phase transition boundaries along with source term or boundary heat flux. We follow a new variational formulation developed in *U. G. Abdulla, Inverse Problems and Imaging, 7,2(2013),307-340* and reformulate ISP as an optimal control problem for the minimization of the L_2 declination of traces of a state vector with the unknown flux and the free boundary as controls. This formulation reduces the effect of measurement errors and needs to solve only a Neumann problem at each step of the minimization process. To prove existence, and provide a numerical method for solution of ISP, we consider a fully discrete problem. We prove well-posedness of the problem in the Sobolev spaces framework, and that interpolated solutions of the discrete problem converge weakly in Sobolev-Hilbert space H^1 to a solution to the Neumann problem via the derivation of two energy estimates for the discrete problem. We further prove that the discrete optimal control problems converge to the continuous problem with respect to functional and with respect to control. (Received July 21, 2014)

1106-35-121 **Daniel T Onofrei*** (onofrei@math.uh.edu). *Active control for fields Modelled by Helmholtz equation.* Preliminary report.

In this presentation we study the problem of active control of fields in the context of scalar Helmholtz equation. Given a source region D_a and $\{v_0, v_1, ..., v_n\}$, a set of solutions of the homogeneous scalar Helmholtz equation in n mutually disjoint "control" regions $\{D_0, D_1, ..., D_n\}$ of $\mathbb{R}^2$ or $\mathbb{R}^3$ respectively, the main objective of the paper is to characterize the necessary boundary data on ∂D_a so that the solution to the corresponding exterior scalar Helmholtz problem will closely approximate v_i in D_i respectively for each $i \in \{0, .., n\}$. We will present the existence of a class of solutions to the problem, discuss the existence of a minimal energy solution and provide numerical support of the results in 2D and 3D as well. We will also present a sensitivity analysis of the approach where questions such as stability and feasibility of the proposed scheme will be discussed (Received July 21, 2014)

1106-35-160 **Anthony N. Johnson*** (anthony.johnson@usma.edu), 601 Swift Road, West Point, NY 10996, and **Theodore V. Hromadka** and **Steven B. Horton**. *Modeling Mixed Boundary Conditions with the Complex Variable Boundary Element Method (CVBEM).*

The Complex Variable Boundary Element Method or CVBEM is a numerical technique that can provide solutions to potential value problems in two or more dimensions by use of an approximation function that is derived from the Cauchy Integral in complex analysis. Given potential values (*i.e.*, a Dirichlet problem) along the boundary, the typical problem is to develop a potential function to solve the governing Laplace equation. In this approach, it is not necessary to know streamline values on the boundary. This modeling approach can be extended to problems where the streamline function is needed because there are known streamline values along the boundary (*i.e.*, a mixed boundary value problem). Two common problems that have such conditions are insulation on a boundary, and fluid flow around a solid obstacle. A demonstration problem of fluid flow is included to illustrate the flownet development capability. (Received August 01, 2014)

1106-35-236 **Arezou Ghesmati*** (aghesmati@math.tamu.edu), Department of Mathematics Mailstop 3368, Texas A&M University, College Station, TX 77843-3368, and **Wolfgang Bangerth** (bangerth@math.tamu.edu), Department of Mathematics Mailstop 3368, Texas A&M University, College Station, TX 77843-3368. *A Residual Based Aposteriori Error Estimation in a Fully Automatic hp–FEM for The 2 and 3-D Stokes Model Problem.*

Aposteriori error estimator as a computable quantity in terms of known quantities such as approximated solution and the data, gives a useful tool to assess the approximation quality in order to improve the solution adaptively. In this research we present a fully automatic hp-adaptive refinement strategy for Finite Element Method, using a residual based aposteriori error estimation which is based on the solution and the data of local boundary value problems. The reliability and also the efficiency for this introduced estimator has been proved. Moreover the contraction convergence is shown and verified in theoretical part. Our results out of implementation for Stokes problem indicates the exponential rate of convergence in our hp-adaptive algorithm. (Received August 13, 2014)

1106-35-311 **Changfeng Gui** (gui@math.uconn.edu), 196 Auditorium Road, Unit 3009, Storrs, CT 06269, and **Tingting Huan*** (tingting.huan@yahoo.com), Room 121, Mathematics Building, 1984 Mathematics Road, Vancouver, BC V6T 122, Canada. *Traveling wave solutions to the combustion and the generalized Fisher-KPP models with fractional Laplacians.*

We show the nonexistence of traveling wave solutions in the combustion model with fractional Laplacian $(-\Delta)^s$ when $s \in (0, 1/2]$. Our method can be used to give a direct and simple proof of the nonexistence of traveling fronts for the usual Fisher-KPP nonlinearity. Also we prove the existence and nonexistence of traveling waves solutions for different ranges of the fractional power s for the generalized Fisher-KPP type model. (Received August 20, 2014)

1106-35-504 **Hong-Ming Yin** (hyin@wsu.edu), Department of Mathematics, Washington State University, Pullman, WA 99164, and **Wen Wang*** (wwang@math.wsu.edu), Department of Mathematics, Washington State University, Pullman, WA 99164. *On the American Option-Pricing Model with a Uncertain Volatility.* Preliminary report.

In this talk I will discuss some properties for the American option price. A comparison principle is approved. Some numerical results will also be presented in the talk. The result confirms a well-known fact about option price in the real financial market. (Received August 31, 2014)

1106-35-571 **Alfonso Castro*** (castro@g.hmc.edu), Department of Mathematics, Harvey Mudd College, Claremont, CA 91711, and **Emily Fischer**. *Rotationally symmetric solutions for a semilinear Laplace-Beltrami equation on spheres.*

We prove the existence of infinitely many regular rotationally symmetric solutions for a semilinear Laplace-Beltrami equation on spheres with superlinear non-linearity. A Pohozaev type identity is obtained which yields necessary growth conditions. The critical exponent arising in this process exceeds the one for radial solutions in balls of $\mathbb{R}^n$. (Received September 02, 2014)

1106-35-577 **Sam J Stewart*** (sstewart@lclark.edu), Lewis and Clark College - MSC 211, 0615 SW Palatine Hill Rd, Portland, OR 97219. *Singularities of Wave Equations with Quadratic Nonlinearities.*

We consider non-linear wave equations $\phi_{tt} - \Delta\phi = Q(\partial\phi)$ in three spatial dimensions. We focus on the case where $Q(\partial\phi) = (\phi_t)^2 - (\phi_r)^2$, as it is a particularly interesting example for studying the long-term behavior. For sufficiently small initial data, global existence of solutions is known, but for large initial data, it is expected that, generically, solutions blow up in finite time. In our work, we seek to understand this singularity formation using both numerical simulations and theoretical considerations. (Received September 14, 2014)

1106-35-589 **Jiao Chen*** (jiaojiaochen@sjtu.edu.cn), Department of Mathematics, Shanghai Jiao Tong University, 800 Dong Chuan Road, Shanghai, 200240, Peoples Rep of China, and **Yanni Zeng** (ynzeng@uab.edu), Department of Mathematics, University of Alabama at Birmingham, Birmingham, AL 35294-1170. *Large Time Behavior of Solutions to Hyperbolic Balance Laws.* Preliminary report.

This talk is concerned with the large time behavior of solutions to the Cauchy problem of general hyperbolic systems of balance laws in one-dimensional space, under the entropy condition and the Shizuta-Kawashima condition. When the initial data is a small perturbation of a constant equilibrium state, we show that the solution approaches to diffusion waves which are predetermined by initial perturbation. Through the pointwise structure of Green's function for the linearized system and analysis on nonlinear coupling of diffusion waves, pointwise time-asymptotic convergence is obtained. Our approach can be applied to dealing with most of the physical models of systems with relaxation, such as the isentropic Euler system with damping, the BGK models with finite discrete velocities, etc. This paper is a joint work with Dr. Yanni Zeng at the University of Alabama at Birmingham. (Received September 02, 2014)

1106-35-621 **Isaac Harris*** (iharris@udel.edu), Department of Mathematical Sciences, University of Delaware, 501 Ewing Hall, Newark, DE 19716, and **Fioralba Cakoni**. *The factorization method for a defective region in an anisotropic material.*

In this presentation we consider the inverse acoustic or electromagnetic scattering problem of reconstructing possibly multiple defective penetrable regions in a known anisotropic material of compact support. We develop the factorization method for a non-absorbing anisotropic background media containing penetrable defects. In particular, under appropriate assumptions on the anisotropic material properties of the media we develop a rigorous characterization for the support of the defective regions form the given fair field measurements. Finally we present some numerical examples in the two dimensional case to demonstrate the feasibility of our reconstruction method including examples for the case when the defects are voids (i.e. subregions with refractive index the same as the background outside the inhomogeneous hosting media). (Received September 03, 2014)

1106-35-658 **Tarek M Elgindi*** (tarekelgindi@gmail.com). *Some results on singular transport equations.*

Our talk will focus on transport equations with singular-integral forcing. These are equations of the form:

$$\partial_t f + b \cdot \nabla_x f = R_x(f)$$

where b is a given divergence-free vector field and R_x is a singular integral operator. This type of transport equation shows up often in the study of fluid equations and can be seen as a prototype for many equations which exhibit local and non-local forces. We are interested in solutions in L^p spaces.

When b is a Lipschitz function:

(1) The singular transport equation may be ill-posed in L^∞ in the sense that bounded initial data may become unbounded immediately.

(2) The singular transport equation is well-posed in the class of functions of bounded mean oscillation (BMO).

(3) The singular transport equation exhibits "well-behaved" growth properties in L^p.

When b is only taken to be bounded:

(1') The singular transport equation may have what we call "cascading solutions" starting from smooth initial data. These solutions belong to L^p for all $p < \infty$ with L^p norms growing on the order of $exp(p)$.

We will discuss most of these results quickly and then focus on the constructions which lead to (1'). (Received September 04, 2014)

1106-35-663 **Junyi Tu*** (junyi@mail.usf.edu), Tampa, FL 33617, and **Yuncheng You**. *Random Attractor of Stochastic Brusselator System with Multiplicative White Noise.*

Asymptotic dynamics of stochastic Brusselator system with multiplicative white noise is investigated in this work. The existence of random attractor is proved through exponential transformation of Ornstein-Uhlenbeck process, which is more challenging in the terms of *a prior* estimates than the exponential transformation of Brownian motion. Further, we show that the random attractor turns out to be a (L^2, H_0^1) random attractor (Received September 04, 2014)

1106-35-665 **Anna L Mazzucato*** (alm24@psu.edu). *Mixing and transport by incompressible flows.*

I will present examples of optimal mixing by incompressible flows under given constraints on the Sobolev norm of the velocity. I will also discuss related results on loss of regularity for solutions of linear transport equations. (Received September 04, 2014)

1106-35-691 **Suzanne Lenhart*** (lenhart@math.utk.edu), University of Tennessee, Dept. of Math. 227 Ayres Hall, 1403 Circle Drive, Knoxville, TN 37996-1320. *Optimal control of PDE models for populations.* Preliminary report.

Using parabolic parabolic partial differential equations, we investigate population strategy questions via optimal control tools. The advective coeffecent is chosen for the control representing the choice of the population to move to benefit its abundance. Controlling the advective coefficient is explored in the case on one population and then in the case of two competing populations. (Received September 04, 2014)

1106-35-695 **Malley M Nason*** (mnason@linfield.edu), 190 SW Brumback Street, Unit #2815, McMinnville, OR 97128. *Asymptotic Behavior of Travelling Wave Solutions to Reaction-Diffusion Equations.*

We will discuss travelling wave solutions to reaction-diffusion equations of the form $u_t = u_{xx} + u^p(1 - u^q)$, which can be used as a mathematical model for various biological phenomena, as well as to model problems in combustion theory. We identify conditions on the wave speed so that travelling wave solutions exist for the case $p \geq 1$ and $q \geq 1$. Moreover, we estimate the rate of decay of the travelling wave solutions. When $p > 1$ and $q \geq 1$ this estimate requires center manifold theory because the typical linear methods fail to work. (Received September 04, 2014)

1106-35-722 **Olivier Pinaud*** (pinaud@math.colostate.edu). *Kinetic models for imaging in random media.*

We will present some transport models for the reconstruction of inclusions in strongly heterogeneous media. These models are based on quadratic quantities in the wavefield that are expected to be more statistically stable than the wavefield itself. Numerical simulations validating the theory will be presented. (Received September 05, 2014)

1106-35-730 **Robert Stephen Cantrell*** (rsc@math.miami.edu), Department of Mathematics, The University of Miami, Coral Gables, FL 33124, and **Chris Cosner** and **King Yeung Lam**. *An infinite dimensional version of the Tube Theorem.*

We discuss an extension of the Tube Theorem from adaptive dynamics to infinite dimensional contexts, including that of reaction-diffusion equations. (Received September 05, 2014)

1106-35-745 **Robert Neill Staniunas*** (staniurn@dukes.jmu.edu) and **Zev Woodstock** (woodstzc@dukes.jmu.edu). *The Hybrid-Bremmer Series Method for an Inverse Scattering Problem: Convergence, Stability, and Error Characterization.*

We present a series solution for an inverse scattering problem with applications in seismic imaging. Starting with the equation for an acoustic wave propagating in a spatially varying medium, we formulate a forward series solution for the scattered wave, then an analogous inverse series that recovers the spatially varying medium from measurements on the subsurface boundary. We explain both the forward and and the inverse problems, and prove convergence, stability and error results for both the forward and the inverse series. (Our analysis is for the one dimensional problem.) (Received September 05, 2014)

1106-35-766 **Narayan Thapa*** (narayan.thapa@minotstateu.edu). *Fréchet Differentiability of Parabolic Partial Differential Equation.*

The second order parabolic partial differential equation with a diffusion coefficient is considered. Continuity of solution map with respect to parameter is shown. The necessary condition for the optimal set of parameter by minimizing the objective functional is established. Weak Gateaux differentiability of solution map is established. Fréchet differentiability of functional is derived. (Received September 06, 2014)

1106-35-795 **Dipendra Regmi***, Farmingdale State College, State University of New York, Farmingdale, NY. *The 2D Euler-Boussinesq equations with a singular velocity.* Preliminary report.

We study the global (in time) regularity problem concerning a system of equations generalizing the two-dimensional incompressible Boussinesq equations. We establish the global existence and uniqueness of solutions to the initial-value problem of this generalized Boussinesq equations when the velocity is "double logarithmically" more singular than the one given by the Biot-Savart law. This global regularity result goes beyond the critical case. This is a joint work with D. KC, L. Tao and J. Wu. (Received September 06, 2014)

1106-35-809 **Mónica Clapp*** (monica.clapp@im.unam.mx), **Marco Ghimenti** and **Anna Maria Micheletti**. *Solutions to a singularly perturbed supercritical elliptic equation on a Riemannian manifold concentrating at a submanifold.*

Many models for pattern formation in various branches of science are based on A.Turing's idea that, in a system of equations modeling two interactive substances, different diffusion rates may lead to nonhomogeneous distributions of these substances.

Showing existence and determining the profile of solutions for this type of models has been a very active area of research during the last three decades. Many results concerning concentration at a point or at a finite number of points are now available. Quite recently, solutions concentrating at higher dimensional manifolds have been shown to exist.

In this talk we shall consider a singularly perturbed semilinear elliptic equation on a closed Riemannian manifold, and show how its geometry can be used to produce solutions which concentrate at manifolds of different positive dimensions, up to some supercritical nonlinearities. (Received September 07, 2014)

1106-35-822 **Michael E. Filippakis*** (mfilip@unipi.gr), Department of Digital Systems,University of, Piraeus, 80, Karaoli and Dimitriou Str, Piraeus, Greece, 18534, and **Nikolaos S Papageorgiou** (npapg@math.ntua.gr), Department of Mathematics, National Technical University,Zografou Campus, athens, 15780. *Existence of Nodal Solutions for Neumann Problems.* Preliminary report.

We consider a nonlinear elliptic Neumann problem driven by a nonhomogeneous differential operator, which is strictly monotone and incorporates as special cases the p-Laplacian, the (p, q)-differential operator and the generalized p-mean curvature differential operator. Using variational methods coupled with suitable truncation and comparison techniques and Morse theory (critical groups), we show that the problem has at least three nontrivial smooth solutions, one positive, the second negative and the third nodal. Also we show that the problem has extremal nontrivial constant sign solutions. (Received September 07, 2014)

1106-35-844 **Junping Shi*** (jxshix@wm.edu), Department of Mathematics, College of William and Mary, Williamsburg, VA 23187. *Steady state solutions of a reaction-diffusion system modeling an autocatalytic chemical reaction with decay.*

Autocatalytic chemical reactions have been identified as one of main nonlinear mechanisms in biochemical procedures. In this talk, the dynamics and steady state solutions of an autocatalytic chemical reaction model with decay in the catalyst are considered. Nonexistence, existence and multiplicity of nontrivial steady state solutions are shown by using energy estimates, upper–lower solution method, bifurcation theory and topological degree theory. The effects of decay order, decay rate and diffusion rates to the dynamical behavior are discussed. This is a joint work with Zhao Yuhua, Wang Yuwen (Harbin Normal University), Zhou Jun (Southwest University). (Received September 07, 2014)

1106-35-845 **Suncica Canic***, Department of Mathematics, 4800 Calhoun Rd., University of Houston, Houston, TX 77025, and **Boris Muha** and **Martina Bukac**. *Fluid-Composite Structure Interaction.*

Composite materials appear in virtually all areas of engineering and in nature. Examples include engineering structures such as boats and aircrafts, or, in biological applications, blood vessels of major human arteries. These materials are exposed to a wide spectrum of dynamic loads. Understanding the interaction between composite materials and the surrounding fluid is important for prevention of catastrophic events in engineered constructs, or for design of medical treatments in case of biological applications. No mathematical results exist so far that analyze solutions to fluid-structure interaction problems with composite structures.

In this talk we make a first step in this direction by presenting a program to study the **existence and numerical simulation** of solutions for a class of problems describing the interaction between a multi-layered, composite structure, and the flow of an incompressible, viscous fluid, giving rise to a fully coupled, **nonlinear moving boundary, fluid-multi-structure interaction problem.** Our results reveal a new physical regularizing mechanism: inertia of the fluid-structure interface regularizes the evolution of the entire solution. (Received September 07, 2014)

1106-35-864 **Sebastian Acosta*** (sacosta@bcm.edu). *Time reversal and inverse problems for radiative transport.*

The goal of our work is to estimate the absorption coefficient from measurements of the outgoing photons after they have traveled through turbid media. This problem arises in biomedical applications such as imaging of biological tissues with near-infrared light, and optical molecular imaging. Our work proposes an iterative technique, which accounts for the scattering effects, to reconstruct the unknown parameters in the transport equation. We prove convergence results. (Received September 08, 2014)

1106-35-896 **Analee M Miranda*** (analee.miranda@us.af.mil), RF Technology Branch, 2241 Avionics Circle, Building 620, WPAFB Dayton, OH 45433, and **Stephanie R Keith**, **Grant Erdmann** and **Loria Wang**. *Age classification of human electromagnetic scattering at ultra high frequency.*

Radar based human detection and classification is a diverse field that is rich with challenging open problems. There are currently several commercial off the shelf computational electromagnetic software that have developed human packages specifically for the purpose of radar based human detection and classification. Most software, however, is not accurate within the Ultra High Frequency (UHF) radar bands. In this paper we carefully develop a theoretical human radar scattering model for UHF. We find that there are unique human-based resonances in the UHF band that aid in classifying a general age class. We also find that we may infer certain physical body indexes from radar scattering measurements. We continue the analysis by comparing the regions of the human body that maximally scatter based on frequency selection. We conclude the paper by listing a set of open problems that have been determined based on our paper's analysis. (Received September 08, 2014)

1106-35-914 **Grace Ann Kennedy*** (grace.kennedy@asu.edu) and **Mohamed Moustaoui**. *A numerical split-explicit method for integration of the Linear Shallow Water Equations.*

I will provide an analysis of a new split-explicit method that combines leapfrog with a fourth-order implicit time filter. The method uses a two time-step technique, where slow propagating modes are treated with the time filter, and fast modes are numerically solved by an implicit method. The slow modes are not updated within the small time-step loop to allow for faster integrations. A comparison to prior schemes and a stability analysis will be given along with an application to numerical weather forecast models. The implementation and application of this scheme will be compared to a case where an exact solution can be derived, the linear shallow water equations. (Received September 08, 2014)

1106-35-952 **Peter Constantin***, Department of Mathematics, Princeton University, Fine Hall, Washington Road, Princeton, NJ 08544. *Lagrangian-Eulerian methods for uniqueness in hydrodynamic systems.*

We present a Lagrangian-Eulerian strategy for proving uniqueness and local existence of solutions of limited smoothness for a class of incompressible hydrodynamic models including generalized Oldroyd-B complex fluid models and zero magnetic resistivity magneto-hydrodynamic systems. (Received September 09, 2014)

1106-35-998 **James V Lambers*** (james.lambers@usm.edu), 118 College Dr #5045, Hattiesburg, MS 39402. *Approximate Diagonalization of Variable-Coefficient Differential Operators Through Similarity Transformations.*

Approaches to approximate diagonalization of variable-coefficient differential operators using similarity transformations are presented. These diagonalization techniques are inspired by the interpretation of the Uncertainty Principle by Fefferman, known as the SAK Principle, that suggests the location of eigenfunctions of self-adjoint differential operators in phase space. The similarity transformations are constructed using canonical transformations of symbols and anti-differential operators for making lower-order corrections. Numerical results indicate that the symbols of transformed operators can be made to closely resemble those of constant-coefficient operators, and that approximate eigenfunctions can readily be obtained. (Received September 09, 2014)

1106-35-1132 **Jiahong Wu*** (jiahong.wu@okstate.edu), Department of Mathematics, 401 Mathematical Sciences, Oklahoma State University, Stillwater, OK 74078. *The two-dimensional Boussinesq equations with fractional dissipation.*

The Boussinesq equations concerned here model geophysical flows such as atmospheric fronts and ocean circulations. Mathematically the 2D Boussinesq equations serve as a lower-dimensional model of the 3D hydrodynamics equations. In fact, the 2D Boussinesq equations retain some key features of the 3D Euler and the Navier-Stokes equations such as the vortex stretching mechanism. The global regularity problem on the 2D Boussinesq equations with partial or fractional dissipation has attracted considerable attention in the last few years. This talk presents recent developments in this direction. In particular, we detail the global regularity result on the 2D Boussinesq equations with vertical dissipation as well as the result for the 2D Boussinesq equations with general critical dissipation. (Received September 10, 2014)

1106-35-1149 **Jesse Ratzkin*** (jesse.ratzkin@uct.ac.za) and **Tom Carroll** (t.carroll@ucc.ie). *Eigenvalues of moving domains in Riemannian manifolds of nonpositive curvature.*

Let (M, g) be a complete Riemannian manifold with nonpositive sectional curvature, and let Ω be a (sufficently small) domain with compact closure. If Ω moves with velocity $e^w \eta$, where η is the unit outward normal of $\partial\Omega$, then $\Omega_s \subset \Omega_t$ for $s < t$. Thus domain monotonicity implies $\lambda(t) = \lambda(\Omega_t)$ is a decreasing function, where λ is the first Dirichlet eigenvalue of the Laplace-Beltrami operator. We give an lower bound for this rate of decrease. Our estimate is isoperimetric, in that equality forces Ω to be isometric to a round ball in Euclidean space. We will also present some results comparing λ before and after a conformal diffeomorphism, which one can view as an extension of the classical Schwarz lemma in complex analysis. Our main result applies to any geometric flow, under appropriate convexity hypotheses, and appears to be new even if the ambient manifold is a Euclidean space. (Received September 11, 2014)

1106-35-1217 **Chloe L Ondracek*** (chloeondracek@rocketmail.com) and **Narayan Thapa** (narayan.thapa@minotstateu.edu). *On the Numerical Solution of the Sine-Gordan Equation using Method of Lines.*

In this work we study the numerical approximation to the Sine-Gordan equation using the method of lines. The method involves a discrete space domain and continuous time domain. The finite difference approximations to the space derivatives are used and compared. A system of second order ordinary differential equations is developed and then converted to systems of first order equations. MATLAB codes will be developed and implemented. (Received September 11, 2014)

1106-35-1333 **Georg Hetzer*** (hetzege@auburn.edu), Department of Mathematics and Statistics, Auburn University, Auburn, AL 36849-5310. *A Reaction-Diffusion Problem with Hysteresis.* Preliminary report.

Energy balance climate models lead to reaction-diffusion equations with slow diffusion on the 2-sphere. A hysteresis term is introduced in order to account for a frequent repetition of sudden and fast warming followed by much slower cooling as observed from paleoclimate proxy data. Existence of global solutions and of a trajectory attractor will be discussed. (Received September 12, 2014)

1106-35-1340 **Alexander Kiselev*** (kiselev@rice.edu), Department of Mathematics, Rice University, 6100 Main street, MS 136, Houston, TX 77005. *Regularity, blow up, and small scale creation in fluids.*

I will describe a recent sharp result on the rate of creation of small scales in the solutions of the 2D Euler equation. I will also indicate connection with well known open questions in three dimensions, and discuss simplified models for which rigorous results are available. (Received September 12, 2014)

1106-35-1383 **P-E Jabin*** (pjabin@umd.edu), CSCAMM and Dpt of Mathematics, University of Maryland, Colleges Park, MD 20742. *Well posedness for solutions to linear kinetic equations with rough force fields.*

We show existence and uniqueness of a DiPerna-Lions flow for relativistic or classical particles subject to rough force field. Typical and important examples include oscillating electric fields or even a Lorentz force where electric and magnetic fields solve the linear Maxwell system in the vacuum but for singular initial conditions. which are only in the physical energy space. We are able to show that it is possible to relax the BV assumption on the force field by a careful analysis of the cancellations over a trajectory. (Received September 12, 2014)

1106-35-1398 **Chuntian Wang*** (wang211@umail.iu.edu), 831 East 3rd St, Bloomginton, IN 47405. *Time Discrete Approximation of Weak Solutions for Stochastic Equations of Geophysical Fluid Dynamics and Applications.*

As a first step towards the numerical analysis of the stochastic primitive equations of the atmosphere and oceans, we study their time discretization by an implicit Euler scheme. From deterministic viewpoint the 3D Primitive Equations are studied with physically realistic boundary conditions. From probabilistic viewpoint we consider a wide class of nonlinear, state dependent, white noise forcings. The proof of convergence of the Euler scheme covers the equations for the oceans, atmosphere, coupled oceanic-atmospheric system and other geophysical equations. We obtain the existence of solutions weak in PDE and probabilistic sense, a result new to the best of our knowledge. (Received September 12, 2014)

1106-35-1534 **Vinodh kumar Chellamuthu*** (vxc1794@louisiana.edu), Department of Mathematics, University of Louisiana at Lafayette, Lafayette, LA 70504, and **Azmy S. Ackleh** and **Kazufumi Ito**. *Finite difference approximations for measure-valued solutions of a hierarchically size-structured population model.*

We consider a quasilinear hierarchically size-structured population model formulated by Ackleh and Ito in 2005. In this model the growth, mortality and reproduction rates are assumed to depend on a function of the population density. The solution to this model can become singular (measure-valued) in finite time even if all the vital rates are smooth. In this paper we develop an implicit first-order finite difference scheme to compute the measure-valued model solution. Convergence analysis for this method is provided. We also present a high resolution second order explicit scheme to compute the solution of the model. Numerical simulations indicate that the second order method is superior in resolving solution-singularities. (Received September 14, 2014)

1106-35-1581 **M. Ignatova*** (ignatova@math.princeton.edu), **I. Kukavica**, **I. Lasiecka** and **A. Tuffaha**. *Well-posedness for an interface damped free boundary fluid-structure model.*

We address a fluid-structure system which consists of the incompressible Navier-Stokes equations and a damped linear wave equation defined on two dynamic domains. The equations are coupled through transmission boundary conditions and additional boundary stabilization effects imposed on the free moving interface separating the two domains. First, we will discuss the local in time existence and uniqueness of solutions. In the second part, we also address the global in time existence for small initial data. This is a joint work with I. Kukavica, I. Lasiecka, and A. Tuffaha. (Received September 14, 2014)

1106-35-1596 **David S Shoup*** (dshoup@gwmail.gwu.edu), Dept of Mathematics, Monroe Hall, 2115 G St NW, Washington, DC 20052. *Boundary droplet formation in a binary inhibitory system.* Preliminary report.

The free energy of a binary system includes an interface energy that favors micro-domain growth and a longer ranging, inhibitory interaction energy that prevents unlimited spreading. In a planar domain, if the two energies are properly balanced, the free energy admits a local minimizer that on the boundary of the domain will take the form of a partial disc. By perturbing these discs, one defines a restricted class of boundary droplets that can be described by internal variables. A local minimizer of each restricted class is found as a fixed point of a nonlinear equation by a contraction mapping argument. After performing another minimization among the local minimizers from all restricted classes, a minimum of minimizers emerges for the system. (Received September 14, 2014)

1106-35-1671 **Hakima Bessaih*** (bessaih@uwyo.edu), 1000 E. University Ave, Dept. 3036, Laramie, WY 82071, and **Yalchin Efendiev** and **Florin Maris**. *Homogenization of the evolution Stokes equation in a perforated domain with a stochastic Fourier boundary condition.*

The evolution Stokes equation in a perforated domain subject to Fourier boundary condition on the boundaries of the holes is considered. We assume that the dynamic is driven by a stochastic perturbation on the interior of the domain and another stochastic perturbation on the boundaries of the holes. The macroscopic (homogenized) equation is derived as another stochastic partial differential equation, defined in the whole non perforated domain. Here, the initial stochastic perturbation on the boundary becomes part of the homogenized equation as another stochastic force. We use the two-scale convergence method after extending the solution with 0 in the wholes to pass to the limit. Due to the particular boundary condition dealt with, we get that the solution of the stochastic homogenized equation is not divergence free. However, it is coupled with the cell problem that has a divergence free solution. (Received September 14, 2014)

1106-35-1704 **Mathew Gluck*** (mrg0019@uah.edu), Shelby Center for Science and Technology, 301 Sparkman Drive, Huntsville, AL 35899. *Classification of Solutions to a Critically Nonlinear System of Elliptic Equations on Euclidean Half-Space.*

For $N \geq 3$ and non-negative real numbers a_{ij} and b_{ij} $(i, j = 1, \cdots, m)$, the semi-linear elliptic system

$$\begin{cases} \Delta u_i + \prod_{j=1}^m u_j^{a_{ij}} = 0 & \text{in } \mathbb{R}_+^N \\ \frac{\partial u_i}{\partial y_N} = c_i \prod_{j=1}^m u_j^{b_{ij}} & \text{on } \partial\mathbb{R}_+^N \end{cases} \qquad i = 1, \cdots, m$$

is considered, where $\mathbb{R}_+^N$ is the upper half of N-dimensional Euclidean space. Under suitable assumptions on the exponents a_{ij} and b_{ij}, a classification theorem for the positive $C^2(\mathbb{R}_+^N) \cap C^1(\overline{\mathbb{R}_+^N})$-solutions of this system is proven. (Received September 15, 2014)

1106-35-1709 **Joseph Conlon** and **Michael Dabkowski*** (mgdabkow@umich.edu), 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109, and **Jingchen Wu**. *Asymptotic Stability of the Diffusive Carr-Penrose Model.* Preliminary report.

Carr and Penrose introduced a simplified model of the Lifschitz-Slyozov-Wagner model for which can be thought of as a mean field approximation for the evolution of particle clusters of various volumes. We will present the various models, describe the relevant quantities, and give examples of self similar solutions. Finally, we will introduce a diffusive version of the Carr-Penrose equations and show that the typical cluster volume of the particle clusters grows linearly in time. (Received September 15, 2014)

1106-35-1718 **Danny Arrigo*** (darrigo@uca.edu), 201 Donaghey Ave., Conway, AR 72035, and **Kyle Barker**. *Symmetries of the Gross-Pitaevskii equation.* Preliminary report.

We consider the classical and nonclassical symmetries of the Gross-Pitaevskii equation (GPE). We will show that the nonclassical symmetries are more general than the classical symmetries. We further consider first order compatibility and the GPE and show a class of compatible equations exists that are not obtainable by the symmetry method. (Received September 15, 2014)

1106-35-1726 **Jerome Goddard II*** (jgoddard@aum.edu) and **R. Shivaji**. *Existence, stability, and bifurcation results for positive solutions for classes of semilinear elliptic boundary value problems with nonlinear boundary conditions.*

In this talk, we will investigate the stability properties of nontrivial positive steady state solutions of semilinear initial-boundary value problems with nonlinear boundary conditions. In particular, we will employ a Principle of Linearized Stability for this class of problems to prove sufficient conditions for stability and instability of positive steady state solutions. These results shed some light on the combined effects of the reaction term and the boundary nonlinearity on stability properties. If time permits, we will also discuss existence results and provide complete bifurcation curves in the case of dimension one. (Received September 15, 2014)

1106-35-1737 **Suzannah G Miller*** (suzannah.miller@my.minotstateu.edu) and **Narayan Thapa** (narayan.thapa@minotstateu.edu). *Comparison of Numerical Procedures in Water Pollutant Transport Modeling.*

Water quality, as indicated by the level of water pollution, can be described through mathematical models of the transport of the pollutant of interest. The concentration of the pollutant at a given location in a water body depends on the natural movement and biochemistry of the water body. A fundamental differential equation of transport can be developed that accounts for advection, dispersion, and external contributions of the pollutant, as well as the nonconservative nature of some pollutants. The integration of the differential equation gives the concentration of the pollutant at any point in the volume of water being considered. This research will examine the development of a model of pollutant transport and look for analytical and numerical solutions. In particular, the solutions from the finite difference method and finite element method will be compared. (Received September 15, 2014)

1106-35-1791 **Ricardo Alonso**, **Irene Gamba** and **Natasa Pavlovic***, University of Texas at Austin, Department of Mathematics, 2515 Speedway Stop C1200, Austin, TX 78712, and **Maja Taskovic**. *The exponential-like moments of the Boltzmann equation without cutoff.*

We consider the spatially homogeneous Boltzmann equation without the Grad's cutoff assumption in the angular cross section, for the case of variable hard potentials, and study the behavior of summability of fractional moments for its solution, leading to generation and propagation results of the so-called "exponential moments".

More specifically, we provide a new proof of the generation of exponential moments of order up to the rate of potentials with the classical non-cutoff assumption. We also investigate a behavior of exponential moments of order beyond the rate of potentials and for that purpose we introduce Mittag-Leffler moments (which can be understood as a generalization of the exponential moments due to the fact that Mittag-Leffler functions are generalized fractional power series) and prove their propagation. (Received September 15, 2014)

1106-35-1808 **Masoud Yari*** (masoud.yari@tamucc.edu), school of engineering and computing sciences, Texas A&M University Corpus Christi, Corpus Christi, TX 78412. *Phase Transition analysis of RD/RDA systems.*

Spatial-bifurcation analysis of time-dependent PDE systems is a suitable method for identifying steady-state bifurcated solutions. It also gives itself more easily to computational tools of bifurcation analysis. By taking this approach, however, we lose many important temporal qualities of the system.

In this talk I will present a spatiotemporal analysis of RD/RDA systems that enables us to identify not only the final steady state solutions but also the missing transient states. I will provide a comprehensive picture of the system's local dynamics in appropriate parametric space where bifurcations happen. (Received September 15, 2014)

1106-35-1916 **F B Petronella*** (frank_petronella@baylor.edu), **Robert DeYeso** (robldeye@ut.utm.edu), **Joshua Barrow** (joshuabarrow@southern.edu) and **Lingju Kong**. .

We study the boundary value system for the two-dimensional quasilinear biharmonic equations

$$\begin{cases} \Delta(|\Delta u_i|^{p-2}\Delta u_i) = \lambda_i w_i(x) f_i(u_1, \dots, u_m), \ x \in B_1, \\ u_i = \Delta u_i = 0, \quad x \in \partial B_1, \ i = 1, \dots, m, \end{cases}$$

where $B_1 = \{x \in \mathbb{R}^2 \ : \ |x| < 1\}$. Under some suitable conditions on w_i and f_i, we discuss the existence, uniqueness, and dependence of positive radially symmetric solutions on the parameters $\lambda_1, \dots, \lambda_m$. Moreover, two sequences are constructed so that they converge uniformly to the unique solution of the problem. An application to a special problem is also presented.
(Received September 15, 2014)

1106-35-1938 **Seckin Demirbas*** (demirba2@illinois.edu), 703 W. High St., Apt. 2, Urbana, IL 61801. *Gibbs' measure and almost sure global well-posedness for one dimensional periodic fractional Schrödinger equation.*

In this talk we will present recent local and global well-posedness results on the one dimensional periodic fractional Schrödinger equation. We will also talk about construction of Gibbs' measures on certain Sobolev spaces and how we can prove almost sure global well-posedness using this construction. (Received September 15, 2014)

1106-35-1966 **Brian W Bell*** (bwbell@asu.edu) and **Mohamed Moustaoui** (mohamed.moustaoui@asu.edu). *A Split Explicit Scheme for Integration of Nonlinear Atmospheric Equations Involving Multiple Timescales.*

This talk will introduce and discuss a new numerical scheme developed to be well suited to solve nonlinear partial differential equations like those which compose global spectral and weather prediction models. The scheme enhances the computationally inexpensive leapfrog scheme by incorporating a high order implicit filter that maintains third order amplitude accuracy while damping unphysical computational modes which are inherent in leapfrog. The scheme is split explicit using two time steps. Slow waves are treated by time filtered leapfrog, while fast waves are treated by a semi-implicit scheme. For each time step, the scheme uses one evaluation compared with three evaluations required by the third-order Runge-Kutta method, a primary shceme currently used in some national weather prediction models. The new scheme is developed and implemented to solve global shallow-water equations on a sphere using spectral methods and to solve Navier Stokes equations. The performance is demonstrated by comparing the results for this scheme with those from third order Runge-Kutta.
(Received September 15, 2014)

1106-35-2020 **Katarina Jegdic*** (jegdick@uhd.edu). *Riemann problems for two-dimensional systems of conservation laws.*

We give an overview of techniques used in analysis of existence of solutions to Riemann problems for two-dimensional systems of conservation laws that model regular shock reflection. We consider three such systems: unsteady transonic small disturbance equation, nonlinear wave system and the isentropic gas dynamics equations. We rewrite the problem for each system using self-similar coordinates and we we obtain free boundary problems that change type. We discuss the main approach (introduced by Keyfitz, Canic and Lieberman) of showing existence of a local solution to each problem using the theory of second order elliptic equations and various fixed-point theorems. (Received September 15, 2014)

1106-35-2069 **Azmy S. Ackleh**, **Xinyu Li** and **Baoling Ma*** (baoling.ma@louisiana.edu). *Parameter estimation in a size-structured population model with distributed states in the recruitment.*

A least-squares method is developed for estimating parameters in a size-structured population model with distributed states in the recruitment. Convergence results for the computed parameters are established. In the numerical simulations, we perform parameter estimation computations with statistical analysis to compare the single state-at-birth versus the distributed states-at-birth model dynamics. (Received September 15, 2014)

1106-35-2076 **Anahit Galstyan*** (agalstyan@utpa.edu), Department of Mathematics, University of Texas-Pan American, 1201 West University Druve, Edinburg, TX 78539. *Semilinear Klein-Gordon equation in FLRW spacetimes.*

We consider waves, which obey the semilinear Klein-Gordon equation, propagating in the Friedmann-Lemaitre-Roberson-Walker spacetimes. The equations in the de Sitter and Einstein-de Sitter spacetimes are the important particular cases. We show the global in time existence in the energy class of solutions of the Cauchy problem.
(Received September 15, 2014)

1106-35-2142 **Walter Craig**, **Amanda French*** (afrench@math.mcmaster.ca) and **Chi-Ru Yang**. *Canonical Transformations of Null Forms.* Preliminary report.

The nonlinear wave equation

$$\Box u = F(u, u', u'') \tag{1}$$

in $\mathbb{R}^{n+1}$, $n \geq 3$, was shown by Klainerman to have a small-data global solution when F satisfies the so-called *null condition*, which imposes an algebraic cancellation on nonlinearities in the direction of the light cone. We examine scalar Hamiltonian null forms from the perspective of Birkhoff normal form transformations, producing a canonical transformation τ which removes the quadratic terms from the Hamiltonian of (1). This enables us to reproduce the results of Klainerman, but also clarifies the relationship between the null condition and three-wave resonance, preserves the Hamiltonian structure of the problem, and establishes a formalism that holds the potential to extend the existing body of results on null forms. (Received September 15, 2014)

1106-35-2266 **Ramesh Karki*** (rkarki@rockets.utoledo.edu), 918 Winding Ridge Drive, Apt 8, Richmond, IN. *Nonlinear Pseudo-differential Equations, Sobolev Gradients & Application to Nonlinear Pseudo-differential Equations.*

We are driven by a problem of finding critical points of an energy type funtional defined on an infinite dimensional Hilbert space (namely a Sobolev Space). To set up such problem, we first consider Sobolev gradient of such funtional as an element of a Sobolev space $H^{\alpha\beta}$, $\alpha \in (0, 1]$, $\beta \in (0, 1)$, then consider the steepest descent (Sobolev gradient descent) equation. Under suitable initial and periodic boundary conditions, we prove existence and uniqueness of semi-flow of this equation and discuss its equilibrium solutions, which are indeed critical points of the functional. (Received September 16, 2014)

1106-35-2308 **Mauricio Alexander Rivas*** (rivasma@wfu.edu). *Linear Elliptic Eigenproblems and Observing Lyapunov Exponents of Infinite-dimensional Dynamics.*

We analyze the set of critical points of a parametrized functional that arises in the study of linear elliptic eigenvalue problems that may include Robin or Steklov boundary conditions. The critical points are shown to be certain eigenfunctions while corresponding critical values are related to the associated eigenvalues. This is joint work with Professor Giles Auchmuty.

We then describe the extent to which Lyapunov exponents of infinite-dimensional dynamical systems, which may arise from evolution PDEs, follow by projecting the dynamics into $\mathbb{R}^N$ using 'typical' nonlinear maps. This is joint work with Professor William Ott. (Received September 16, 2014)

1106-35-2314 **Bevin Laurel Maultsby*** (maultsby@umn.edu). *Geometry of radial states in p-Laplacian equations.* Preliminary report.

We consider radially symmetric positive solutions to $\Delta_p u + f(u) = 0$ on a ball centered at the origin in $\mathbb{R}^n$. The union of all such solutions to this quasilinear elliptic equation forms an invariant manifold. We use homotopy methods and two integral expressions that arise from vector fields on the manifold to show that for a certain class of f, there can be at most one such solution satisfying $\Delta_p u + f(u) = 0$ for $1 < p \leq 2$. Extensions to sign-changing solutions will be presented too. (Received September 16, 2014)

1106-35-2458 **Henok Mawi*** (henok.mawi@howard.edu). *Symmetry Properties of Solution of a System of Elliptic PDEs arising from a Tumor Model.* Preliminary report.

Let Ω be a bounded domain. The following overdetermined system of elliptic PDEs arise in a tumor model.

$$\begin{aligned} &\Delta\sigma = \sigma && \text{in} \quad \Omega \\ &\Delta p = -\mu(\sigma - \tilde{\sigma}) && \text{in} \quad \Omega \\ \sigma = 1, \quad p = \kappa, \quad \text{and} \quad &\frac{\partial p}{\partial n} = 0 && \text{on} \quad \partial\Omega. \end{aligned}$$

Here κ is the mean curvature, $0 < \tilde{\sigma} < 1$ is a given equilibrium level and $\mu > 0$ is a small constant. We will discuss the symmetry properties of σ and p. (Received September 16, 2014)

1106-35-2486 **Zhaosheng Feng*** (zsfeng@utpa.edu), Department of Mathematics, University of Texas—Pan American, Edinburg, TX 78539. *Degenerate parabolic system and its approximate solutions.*

In this talk, we are concerned with approximate solutions to a degenerate parabolic system. We provide a connection between the Abel equation of the first kind, an ordinary differential equation that is cubic in the unknown function, and the degenerate parabolic system, a partial differential equation that is the dispersion model of biological populations with both density-dependent diffusion and nonlinear rate of growth. We present the integral forms of the Abel equation with the initial condition. By virtue of the integral forms and the Banach Contraction Mapping Principle we derive the asymptotic expansion of bounded solutions in the Banach space, and use the asymptotic formula to construct approximate solutions to the degenerate parabolic system. (Received September 16, 2014)

1106-35-2566 **Maya Chhetri*** (maya@uncg.edu), Department of Mathematics and Statistics, UNC Greensboro, Greensboro, NC 27402, and **Petr Girg**. *Continua of solutions for asymptotically linear systems of three equations.*

We will consider an asymptotically linear system of three semilinear equations satisfying Dirichlet boundary conditions. The nonlinear perturbations are Carathéodory functions that are bounded by some appropriate nonnegtaive function. There are only two simple eigenvalues, associated to the linear part, whose corresponding eigenfunctions are componentwise nonnegative. We will discuss bifurcation of positive solutions from infinity from these simple eigenvalues. In particular, we will provide sufficient conditions under which the system has bifurcation of positive solutions (from infinity) from both, one, or none of the simple eigenvalues. (Received September 16, 2014)

1106-35-2573 **Colton James Willig*** (willig@live.unc.edu), 100 Melville Loop, Apt. 13, Chapel Hill, NC 27514. *Nonlinear Geometric Optics for Reflecting and Evanescent Pulses.* Preliminary report.

Weakly nonlinear geometric optics expansions of highly oscillatory reflecting and evanescent pulses are considered for a general class of differential operators. Through rigorous error analysis one can demonstrate that the leading term in these expansions is suitably close to the uniquely determined exact solution. The pulses considered reflect off fixed non characteristic boundaries in a spectrally stable way (introduced by Kreiss); some of which rapidly dissipate at they pass into the interior. The results in this paper provide a generalization to the work of Coulombel and Williams in "Nonlinear geometric optics for reflecting uniformly stable pulses" (J. Differential Equations 255), as the boundary frequency is considered not only in the hyperbolic region, but also in the mixed and elliptic region. Furthermore the boundary data considered in this paper is more general; it need not decay as strongly as the boundary data considered in Coulombel and William's paper. (Received September 16, 2014)

1106-35-2581 **Ugur Abdulla** and **Jonathan Goldfarb*** (jgoldfar@fit.edu). *Numerical Methods for Solving Optimal Control Problems for the Second Order Parabolic PDEs.*

We consider inverse Stefan problem where information on the heat flux on the fixed boundary is missing and must be found along with the temperature and free boundary. We employ an optimal control framework where boundary heat flux and free boundary are components of the control vector and optimality criteria consists of the minimization of the sum of L_2-norm declinations from the measurement of the temperature at the final moment and information on the phase transition temperature on the free boundary. This approach allows one to tackle situations when the phase transition temperature is not known explicitly, but is available through measurement with possible error. Well-posedness in a Sobolev spaces framework is proved and the convergence of semi-discrete optimal control problems to the original problem both with respect to cost functional and control is established. Fréchet differentiability of the continuous and discrete problems is considered. The method of proof lends itself to the development of iterative numerical methods of lower computational cost since for every given control vector the parabolic PDE is solved in a fixed region instead of full free boundary problem. The numerical method is implemented to solve example problems with nonsmooth data. (Received September 16, 2014)

1106-35-2621 **Ramjee Sharma*** (rsharma@devry.edu), DeVry University, One West Court Square, Decatur, GA 30030. *Modeling the 2d surface quasigeostrophic equations from the Euler equations.*

The inviscid 2d quasigeostrophic equation is given by

$$\partial_t \theta + u \cdot \nabla \theta = 0, \nabla \cdot u = 0,$$

where $\theta = \theta(x,t)$ is a scalar and u is the velocity field given by the stream function ψ through the following relation $u = \nabla^{\perp}\psi$, and $(-\Delta)^{1/2}\psi = \theta$. This is one of the outstanding open problems in non linear partial differential equations. In this talk we will present numerical and analytic aspects of a model equation that connects the 2d quasigeostrophic equaitons and 2d Euler equation. Since we already know the solution of 2d Euler equation, our results will help understand some important aspects of the unsolved mystry of 2d quasigeostrophic equations. We will also present similarities between 2d quasigeostrophic equations and 3d Euler equation. (Received September 16, 2014)

1106-35-2682 **Dmitry Glotov*** (dglotov@auburn.edu) and **Nan Jiang**. *Slow coarsening in the Allen-Cahn model.* Preliminary report.

Coarsening refers to the evolution of patterns of clusters in which the area of interfaces tends to decrease over time. This phenomenon is manifested in the models for foams, grain structure in alloys, molecular beam epitaxy, etc. The rates of coarsening are physically relevant since they are readily observable both empirically and in the models. We study the rates of coarsening in the Allen-Cahn model and will present estimates of these rates in the form of power laws. The method is based on the framework developed by Kohn and Otto which links the length scale of the system with its energy. The method relies on an interpolation inequality, a dissipation inequality, and an ODE argument and produces time-averaged one-sided estimates of the energy. (Received September 16, 2014)

1106-35-2716 **Karen Yagdjian*** (yagdjian@utpa.edu), Department of Mathematics, University of Texas-Pan American, 1201 West University Drive, Edinburg, TX 78539. *Integral transform approach to the initial-value problem for the evolution equations.*

In this talk we describe some integral transform that allows to write solutions of the problem for one partial differential equation via solution of another one. This transform was used to investigate several well-known equations such as the Tricomi equation, the Klein-Gordon equation in the de Sitter and Einstein-de Sitter spacetimes. A generalization given in this talk allows us to consider also generalized Tricomi equation, the Euler-Bernoulli beam equation, and the Klein-Gordon equations with coefficients depending on the spatial variables. (Received September 16, 2014)

1106-35-2725 **Nsoki Mavinga*** (nmaving1@swarthmore.edu), Department of Mathematics and Statistics, Swarthmore College, PA , and **Rosa Pardo**. *Bifurcation from infinity for reaction-diffusion equations subject to nonlinear boundary conditions.*

We consider a reaction diffusion equation under nonlinear boundary conditions where the nonlinearities are asymptotically linear at infinity, and depend on a parameter. We prove that as the parameter crosses some critical values a resonance type phenomenon provides solutions that bifurcate from infinity. (Received September 16, 2014)

1106-35-2728 **M. N. Nkashama*** (nkashama@math.uab.edu), Department of Mathematics, University of Alabama at Birmingham, Birmingham, AL 35294-1170. *Asymptotic Behavior for Neutral Functional PDEs with General Boundary Conditions.* Preliminary report.

We shall present convergence results for initial boundary value problems for neutral functional partial differential equations for which each and every constant function is a stationary solution. As a special case, we derive asymptotic constancy results for delay functional PDEs. (Received September 16, 2014)

1106-35-2815 **Henri Berestycki** and **Tianling Jin***, 5734 S. University Ave, Department of Mathematics, University of Chicago, Chicago, IL 60637, and **Luis Silvestre**. *Propagation in a nonlocal reaction diffusion equation with spatial and genetic trait structure.*

In joint work with H. Berestycki and L. Silvestre, we study the interplay between traits present in a species and how the species interacts with the environment, and analyze models that take into account jointly the evolution and the ecology. We prove existence and uniqueness of traveling fronts, and asymptotic speed of propagation for a nonlocal reaction diffusion equation with spatial and genetic trait structure. (Received September 16, 2014)

1106-35-2834 **Andrea R Nahmod*** (nahmod@math.umass.edu). *The nonlinear Schrodinger equation on tori: integrating harmonic analysis, geometry and probability.* Preliminary report.

The field of nonlinear dispersive and wave equations has undergone significant progress in the last twenty years thanks to the influx of tools and ideas from nonlinear Fourier and harmonic analysis, geometry, analytic number theory and most recently probability, into the existing functional analytic methods.

In this talk we concentrate on the semi linear Schrodinger equation defined on tori and discuss the most important developments in the analysis of these equations. In particular, we will discuss recent work by Bourgain and Demeter proving the full range of Strichartz estimates on regular and irrational tori and thus settling an important earlier conjecture by Bourgain. (Received September 16, 2014)

1106-35-2894 **Dhanapati Adhikari*** (dadhikari@marywood.edu), Departmenet of Mathematics and Computer, Sciecne, Marywood University, 2300 Adams Avenue, Scranton, PA 18509. *The 2D incompressible Boussinesq equations with partial dissipation.*

This talk presents the recent works on the global regularity issue of the 2D Boussinseq equations with partial dissipation. (Received September 17, 2014)

1106-35-2933 **Tingting Huan*** (tingting@math.ubc.ca), Room 121 Mathematics Building, 1984 Mathematics Road, Vancouver, BC v6T 1Z2, Canada, and **Changfeng Gui**. *Traveling fronts to reaction diffusion equations with fractional Laplacian.*

We consider the traveling fronts of the reaction diffusion equation:

$$u_t + (-\Delta)^s u = f(u), \quad \text{in } \mathbb{R} \times \mathbb{R},$$

for $f \in C^1(\mathbb{R})$. We show the nonexistence of traveling fronts in the combustion model with fractional Laplacian $(-\Delta)^s$ when $s \in (0, 1/2]$. Our method can be used to give a direct and simple proof of the nonexistence of traveling fronts for the usual Fisher-KPP nonlinearity. Also we prove the existence and nonexistence of traveling waves solutions for different ranges of the fractional power s for the generalized Fisher-KPP type model. When considering the Allen-Cahn type nonlinearity, we show the approach of the solution to the traveling front for a large range of initial value problems. (Received September 17, 2014)

37 ► Dynamical systems and ergodic theory

1106-37-22 **Omer Angel** and **Alexander Kechris**, CA , and **Russell Lyons*** (rdlyons@indiana.edu), IN. *Random orderings and unique ergodicity of automorphism groups.*

Is there a natural way to put a random total ordering on the vertices of a finite graph? Natural here means that all finite graphs get an isomorphism-invariant random ordering and induced subgraphs get the random ordering that is inherited from the larger graph. Thus, the uniformly random ordering is natural; are there any others? What if we restrict to certain kinds of graphs? What about finite hypergraphs or finite metric spaces? We discuss these questions and sketch how their answers give unique ergodicity of corresponding automorphism groups; for example, in the case of graphs, the group is the automorphism group of the infinite random graph. (Received July 17, 2014)

1106-37-41 **Nai-Chia Chen*** (chen1945@umn.edu), 206 Church St SE, Minneapolis, MN 55455. *Symmetric Periodic Orbits in Three Sub-Problems of the N-body Problem.*

The Newtonian n-body problem studies the motion of n point masses moving in the Euclidean space, under the influence of their mutual gravitational attraction. The motion is determined by the system of differential equations:

$$\ddot{\mathbf{x}}_i = \sum_{j \neq i}^{n} m_j \frac{\mathbf{x}_j - \mathbf{x}_i}{|\mathbf{x}_j - \mathbf{x}_i|^3}, \quad \mathbf{x}_i \in \mathbf{R}^3,$$

where $\mathbf{x}_i$ and m_i represent the position and the mass of the i-th mass respectively.

We consider three sub-problems of the N-body problem that have two degrees of freedom, namely the $n-$pyramidal problem, the planar double-polygon problem, and the spatial double-polygon problem. We prove the existence of several families of symmetric periodic orbits, including "Schubart-like" orbits and brake orbits, by using topological shooting arguments. (Received May 21, 2014)

1106-37-70 **Mahmoud Najafi**, Ashtabula, OH , and **D Wayne Fincher*** (dfincher@kent.edu), 6058 Lake St, Kingsville, OH 44048. *Treatment for Analytical Solution of Nonlinear Oscillation System Via Decomposition Method.*

In this work, the attempt have been made to illustrate analytical approximate closed form solutions of oscillating systems which are represented by

$m\ddot{u} + f(u, \dot{u}, c, k) = 0,$

i.e., Duffing and Van der Pol equations. To this end, the Adomian Decomposition Method (ADM) has been employed to accomplish analytical solutions to these differential equations. The results are compared with accurate numerical computations; i.e., Runge-Kutta, which show that ADM is a high performance and accurate method to use for the analytical solution of nonlinear physical problems. (Received June 26, 2014)

1106-37-115 **Rashad U Abdulla*** (abdullar@sas.upenn.edu), 4023 Locust Street, Philadelphia, PA 19104, **Ugur G Abdulla** (abdulla@fit.edu), 3627 Mount Carmel Lane, Melbourne, FL 32901, **Batul Kanawati**, California State University of Long Beach, and **Anders Ruden**, University oF Redlands, CA. *On the Structure of Minimal $4(2k+1)$-orbits of the Continuous Endomorphisms on the Real Line and Universality in Chaos.*

We consider the problem on the structure of the periodic orbits of period $4(2k+1)$, $k = 1, 2, ...$ of the continuous real line endomorphisms which are minimal with respect to Sharkovski ordering. By developing the new method suggested in *Abdulla et al. J. of Diff. Equat. and Appl., 19,8(2013), 1395-1416,* it is proved that independent of k, there are 64 types of digraphs (and cyclic permutations) with accuracy up to inverse digraphs. We apply this result to the problem on the distribution of periodic windows within the chaotic regime of the bifurcation diagram of the one-parameter family of logistic type unimodal maps. We confirm through numerical analysis the conjecture made in a recent JDEA paper that the first two appearances of all the $2^n(2k+1)$-periodic windows with $k \geq 3$, as well as first appearances of $5 \cdot 2^n$- and $3 \cdot 2^n$-orbits while increasing the parameter are distributed according to a universal law. Every orbit has unique cyclic permutation and digraph independent of the unimodal map. Another revelation of this research is the refinement of the universal law for the third and fourth appearances of the periodic orbits. Understanding the nature and characteristics of this universal route is an outstanding open problem for future investigations. (Received July 21, 2014)

1106-37-200 **Jessica C Dyer*** (dyer3@uic.edu), 800 S. Wells St, APT 727, Chicago, IL 60607. *Bratteli diagrams for weak solenoids.*

A weak solenoid, in the sense of McCord and Schori, induces a minimal equicontinuous action of a finitely generated group G on a Cantor space X. We use the coding method for such actions, as developed in the paper "Homogeneous matchbox manifolds" in Transactions AMS, 2013 by Clark and Hurder, to construct an "almost finite presentation" representing (X, G). We then use this presentation to construct a Bratteli diagram with group actions that captures the partially homogeneous dynamics of weak solenoids.

This work is joint with Steven Hurder and Olga Lukina. (Received August 08, 2014)

1106-37-210 **Mohammad Javaheri***, 515 Loudon Road, Siena College, School of Science, Loudonville, NY 12211. *Dynamics of semigroup actions of linear fractional transformations.*

Positive continued fractions are viewed as the orbit of 1 under the action of the semigroup of functions generated by r(x)=1/x and s(x)=x+1. The fixed points of the elements of this semigroup contain purely periodic continued fractions (which are the reduced surds by Lagrange's theorem). In this talk, we consider the fixed points of the elements of semigroups generated by general pairs of linear fractional transformations. We discuss how the topological transitivity of a non-commutative semigroup action implies the denseness of its fixed point set. (Received August 11, 2014)

1106-37-221 **Hiroki Sumi*** (sumi@math.sci.osaka-u.ac.jp), Department of Mathematics, Graduate School of Science, Osaka University, 1-1 Machikaneyama, Toyonaka, Osaka 560-0043, Japan. *Negativity of Lyapunov Exponents of Generic Random Dynamical Systems of Complex Polynomials.*

In this talk, we consider random dynamical systems of complex polynomial maps on the Riemann sphere. It is well-known that for each rational map f of degree two or more, the Julia set is a non-empty perfect compact set, the dynamics of f on the Julia set is chaotic, and for the set A of initial points z in the Riemann sphere at which the Lyapunov exponent is positive, the Hausdorff dimension of A is positive. However, we show that for a generic i.i.d. random dynamical system of complex polynomials, all of the following (1) and (2) holds, due to the effect of randomness.

(1) For all but countably many initial points z in the Riemann sphere, for almost every sequence of polynomials, the Lyapunov exponent along the sequence starting with z is negative.

(2) For all points z in the Riemann sphere, the orbit of the Dirac measure at z under the dual map of the transition operator of the system converges to a periodic cycle of probability measures on the Riemann sphere.

Note that each of (1) and (2) cannot hold in the usual iteration dynamics of a single rational map f of degree two or more.

References: H. Sumi, Cooperation principle, stability and bifurcation in random complex dynamics, Adv. Math. 245 (2013), 137-181. (Received August 12, 2014)

1106-37-258 **Buddhi R Pantha*** (pantha@math.utk.edu), 2718 Painter Avenue, Apt A-104, Knoxville, TN 37919, and **Suzanne Lenhart**. *Optimal Control in an ODE/DE Model for a Massive anthrax Outbreak: A preliminary Report.* Preliminary report.

Anthrax is a rapidly fatal, infectious disease which occurs in many animal species, particularly herbivore mammals and is one of the main causes of population decline in several national parks worldwide. Since the anthrax spores can survive in soil and these spores can be found in most parts of the world, clearing anthrax spores from the environment is practically impossible. As the infected animals face inevitable death and each carcass contributes bacteria in the surrounding environment, controlling new infection and proper disposal of the carcasses are the only feasible ways to control the disease. In this project, we extend an existing mathematical model for anthrax epizootic by introducing two commonly used controls in the wild : vaccination and carcass removal. We also introduce a new compartment for vaccinated animals. Model parameters are estimated using real data . We investigate the effect of allocating effort to vaccination and carcasses removal on disease transmission. Preliminary numerical results will be presented. (Received August 15, 2014)

1106-37-453 **Judy Kennedy Anita Kennedy*** (kennedy9905@gmail.com), Department of Mathematics, PO Box 10047, Lamar University, Beaumont, TX 77710, and **Van Nall** and **Goran Erceg**. *Dynamics of the shift map on inverse limits with set-valued functions.* Preliminary report.

Suppose $f : I \to 2^I$ is a upper semicontinuous bonding map. Let $M = \varprojlim f = \{(x_0, x_1 ...) : x_{i-1} \in f(x_i) \text{ for } i > 0\}$. Even though f is not even a function in the usual sense, it induces a continuous function σ from M onto M. The function σ is called the shift map on M, since for $\mathbf{x} = (x_0, x_1, ...) \in M$, $\sigma(\mathbf{x}) = \sigma(x_0, x_1, ...) = (x_1, x_2, ...)$. M is called an inverse limit on set-valued functions, or, equivalently, a generalized inverse limit. These objects were introduced in 2003 by W. Mahavier, and they present a new method of understanding the dynamical behavior of set-valued functions.

While much work by many researchers has been done on understanding the topology of these spaces, we are just beginning a study of the dynamical properties exhibited by the shift map σ. While this is very much work in progress, we will discuss properties that imply that the shift map σ has positive topological entropy, topological transitivity, and perhaps other properties.

(Received August 28, 2014)

1106-37-460 **Zhifu Xie***, Department of Mathematics and Computer Scienc, Petersburg, VA 23806, and **Tiancheng Ouyang**. *Variational method with SPBC and periodic solutions in N-body problems.*

In this talk, we will present some new results by applying variational method with SPBC to prove the existence of periodic or quasi-periodic solutions in Newtonian N-body problem. Numerical simulations will also be presented.

(Received August 28, 2014)

1106-37-503 **François Ledrappier*** (fledrapp@nd.edu), Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556-4618. *Boundary measures minimizing the Rayleigh quotient.* Preliminary report.

Let M be a compact manifold with negative curvature, $\widetilde{M}$ its universal cover, $\partial\widetilde{M}$ the boundary at infinity of $\widetilde{M}$. Olivier Mohsen defined the Rayleigh quotient of an equivariant family of measures on $\partial\widetilde{M}$. We show (joint work with Seonhee Lim) that there exist a minimizing family. In this talk, we describe the construction of this minimizing family and some of its properties. (Received August 31, 2014)

1106-37-516 **Russell Lodge*** (r.lodge@jacobs-university.de), **Yauhen Mikulich** and **Dierk Schleicher**. *A combinatorial classification of postcritically finite Newton maps.*

It will be shown that every postcritically finite Newton map gives rise to a finite forward invariant graph containing all postcritical points, called the extended Newton graph. On the other hand, an extended Newton graph can be extended to a branch covering from the two-sphere to itself, and using Thurston's theorem it will be shown that this branch covering is equivalent to a Newton map. (Received September 01, 2014)

1106-37-562 **Lori Alvin*** (lalvin@du.edu) and **Nic Ormes**. *Minimal Cantor Omega-Limit Sets.*

In this talk we investigate unimodal maps f for which no iterate c_n of the turning point c is recurrent under f and the omega-limit set $\omega(c, f)$ is a minimal Cantor set. Given a non-periodic minimal sequence $r \in \mathcal{A}^{\mathbb{N}}$, we provide a characterization for when $u \in \mathcal{A}^{\mathbb{N}}$ is such that $\omega(u, \sigma) = \omega(r, \sigma)$. We then prove that the set of parameters for symmetric tent maps T_s for which $\omega(c, T_s)$ is a minimal Cantor set and $c_n \notin \omega(c, T_s)$ is dense in $[\sqrt{2}, 2]$. Modifications are provided that can be used to generate sequences $u \in \mathcal{A}^{\mathbb{N}}$ for which $\omega(u, \sigma) = X$, where $X \subseteq \mathcal{A}^{\mathbb{N}}$ is a shift space with specific properties. (Received September 02, 2014)

1106-37-582 **Jane M. Hawkins*** (jmh@math.unc.edu), Mathematics Department CB #3250, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599. *Dynamics of dianalytic maps on Klein surfaces.* Preliminary report.

We discuss analytic maps of the sphere, the torus, and the punctured plane with extra symmetries; namely they project to well-defined maps on corresponding nonorientable Klein surfaces. We consider Julia and Fatou sets on the Klein surfaces and discuss some topological dynamical and ergodic properties. In particular we construct many examples where the Julia set is the entire Klein surface. (Received September 02, 2014)

1106-37-644 **Lennard F Bakker*** (bakker@math.byu.edu), Provo, UT 84602, and **Todd Fisher**. *Open sets of diffeomorphisms with trivial centralizer in the C^1 topology.*

On the torus of dimension 2, 3, or 4, we show that the subset of diffeomorphisms with trivial centralizer in the C^1 topology has nonempty interior. We do this by developing two approaches, the fixed point and the odd prime periodic point, to obtain trivial centralizer for an open neighbourhood of Anosov diffeomorphisms arbitrarily near certain irreducible hyperbolic toral automorphisms. (Received September 03, 2014)

1106-37-679 **Ethan Koenig*** (ethankoenig@gmail.com), Department of Mathematics, 310 Malott Hall, Cornell University, Ithaca, 14853, and **Jessica Walker** (jalise.walker@gmail.com), Mary Baldwin College, P.O. Box 1500, Staunton, VA 24402. *Bifurcation scenarios in external cavity and delay-coupled semiconductor lasers.*

We investigate various bifurcation scenarios in external cavity (single) and mutually delay-coupled semiconductor lasers. The behavior of these lasers is described by the Lang-Kobayashi complex delay differential equation system. This system contains a number of parameters; we considered two scenarios in our research. The first one was the occurrence of Hopf bifurcations when the feedback strength is changing; we identified the regions in the parameter space where certain special solutions (called external cavity mode solutions) lose stability and new types of solutions appear and persist for certain feedback strengths. We also described where these types of solutions disappear from the phase space. The second area of investigation concerned delay-coupled semiconductor lasers; we examined the geometric background underlying the saddle-node bifurcation structure behind compound laser mode (CLM) solutions. We identified the mechanism which drives the appearance of new CLM solutions as the coupling rate is changing for various detuning values. Regions of existence of different types of solutions were created on the coupling rate - detuning parameter plane. (Received September 04, 2014)

1106-37-686 **Jamie J Walton*** (jamie.walton@york.ac.uk), Department of Mathematics, University of York, Heslington, York, YO10 5DD, United Kingdom. *Frequency spectrums of cut-and-project sets.*

Given a Delone set Y (that is, a point set of Euclidean space which is relatively dense and uniformly discrete), one may consider its finite sub-patches as analogous to finite sub-words of some infinite word. Given a notion of size for such patches one could, for example, study the growth rate of the number of translation classes of patches of size r as $r \to \infty$, which provides a notion of complexity for the point set. In another direction, supposing that Y has uniform patch frequencies, one may consider the set of frequencies of patches of size r. We consider an important class of Delone sets, the so called cut-and-project sets. Such a setup is determined by a system of linear forms, along with a choice of "window". In this talk we will discuss how, for certain windows, Diophantine properties of the linear forms forces the number of frequencies of patches of size r to stay low, and in some cases even bounded, as $r \to \infty$. (Received September 04, 2014)

1106-37-697 **Zijian Yao*** (zijian_yao@brown.edu), 7285 Brown University, Providence, RI 02912. *The point of collapse under pentagram maps.*

The pentagram map, introduced by Schwartz, has been studied recently in a series of papers. It maps a polygon in the projective plane to another one by taking intersections of successive 2-diagonals. Schwartz showed that an axis-aligned polygon collapses to a point under a predictable number of iterations of the pentagram map. Glick gave a different proof using cluster algebras, and conjectured that the point of collapse is always the center of mass of the axis-aligned polygon.

In this talk, we give a proof of Glick's conjecture, and generalize the statement to higher and lower dimensional pentagram maps. For the lower pentagram map, we define a new dynamical system – the mirror pentagram map – and show a closely related result. In addition, the mirror pentagram map provides a geometric description for the lower pentagram map, defined algebraically by Gekhtman, Shapiro, Tabachnikov and Vainshtein. (Received September 04, 2014)

1106-37-769 **Olusegun M Otunuga*** (otunuga@marshall.edu), Department of Mathematics, Marshall University, One John Marshall Drive, Huntington, WV 25755, and **Gangaram S Ladde** (gladde@usf.edu), Department of mathematics and Statistics, University of South Florida, 4202 E Fowler Ave, CMC 342, Tampa, FL 33620. *Two-scale Network Dynamic Model for Energy Commodity Process.* Preliminary report.

A multivariate stochastic model with and without external random interventions are developed. Random intervention process is described by a continuous jump process. The developed mathematical model is utilized to examine the relationship between different energy commodity spot prices. Also, an interconnected discrete-time dynamic system of local sample mean and variance processes is developed. The byproduct of this work initiates alternative innovative approach for state and parameter estimation problems for continuous time stochastic dynamic models. Moreover, the presented Local Lagged adapted Generalized Method of Moments (LLGMM) exhibits the balance between model specification and model prescription of continuous time dynamic processes in biological, chemical, engineering, financial, medical, physical and social sciences. Using the developed multivariate stochastic model with and without external random interventions, the usefulness of the LLGMM approach is illustrated by applying to energy commodity data sets for state and parameter estimation problems. Moreover, the forecasting and confidence-interval problems are also investigated. (Received September 06, 2014)

1106-37-810 **Aijun Zhang*** (zhangai@tigermail.auburn.edu), 5110 Spruce Street 3R, Philadelphia, PA 19139, and **Erik S Van Vleck**. *Transition fronts of Fisher-KPP equations in locally spatially inhomogeneous patchy environments.*

The current talk is devoted to the study of spatial propagation dynamics of species in locally spatially inhomogeneous patchy environments or media. For a lattice differential equation with monostable non-linearity in a discrete periodic media, it is well-known that there exists a minimal wave speed such that a traveling wave exists if and only if the wave speed is above this minimal wave speed. We show that strongly localized spatial inhomogeneous patchy environments may prevent the existence of transition fronts. Transition fronts may exist in weaker localized spatial inhomogeneous patchy environments but only in a finite range of speeds, which implies that it is plausible to obtain a maximal wave speed such that a transition front exists. (Received September 07, 2014)

1106-37-866 **Joyce Akinyi Otieno*** (jaotieno@maseno.ac.ke), Maseno University, Private Bag, Maseno, Kenya, and **Joseph Y. T Mugisha**, **Betty K Nannyonga** and **Paul O. Oleche**. *Parameter Driven Dynamics of Trypanosomiasis in a Cattle Population* .

In this paper we study the disease dynamics of trypanosomiasis in a cattle population. The compartmental model presented includes the wild animal population which provides an alternative feeding source for the tsetse fly. An epidemiological parameter, the basic reproduction number is calculated. Based on this parameter, conditions for the global stability of the disease-free and endemic equilibrium points of the model are established. To aid decision making on which parameters to monitor in order to control the disease, a sensitivity analysis of the parameters which define the basic reproduction number is carried out. Results obtained from the sensitivity analysis indicate that the parameters with the highest influence on the spread of the disease are the vector biting rate, the vector survival rate and the vector death rate. These results indicate that an effective control of the disease would require a reduction of the contact rate between the cattle and the vector population.

Subject Classification: Applied Mathematical Sciences
Keywords: Parameter-driven, vector biting rate, vector survival rate. (Received September 08, 2014)

1106-37-911 **Martin M Salgado-Flores*** (mmsalgadoflore@email.wm.edu), 802 Hamder Way, Newport News, VA 23602, and **Yu-Min Chung** and **Sarah Day**. *Dynamics at a Finite Resolution: A Study of Isolating Neighborhoods.* Preliminary report.

Conley Index Theory has inspired the development of rigorous computational methods to study dynamics. These methods construct *outer approximations*, a combinatorial representation of the system, which allows us to represent the system as a directed graph. Invariant sets appear as combinations of vertices and edges on the resulting digraph. Conley Index Theory relies on isolating neighborhoods, which are maximal invariant sets that meet an isolation condition, to describe the dynamics of the system. In this work, we present a computationally efficient and rigorous way of computing all isolating neighborhoods given an outer approximation. We improve upon an existing algorithm that "grows" isolating neighborhoods individually and requires an input size of 2^n, where n is the number of grid elements used for the outer approximation. (Received September 15, 2014)

1106-37-942 **James P Kelly*** (j_kelly@baylor.edu) and **Timothy Tennant**. *Topological Entropy of Set-valued Functions.* Preliminary report.

Let (X, d) be a compact metric space, and let f be a set-valued function on X. For each $n \in \mathbb{N}$, define the set of *n-orbits* to be

$$\mathrm{Orb}_n(f) = \{(x_0, \ldots, x_n) \big| x_i \in f(x_{i-1}) \text{ for } 1 \leq i \leq n\}.$$

Given $n \in \mathbb{N}$ and $\varepsilon > 0$, a set $S \subseteq \mathrm{Orb}_n(f)$ is called an (n, ε)*-spanning set* if, for every $(x_0, \ldots, x_n) \in \mathrm{Orb}_n(f)$, there exists $(s_0, \ldots, s_n) \in S$ such that $d(s_i, x_i) < \varepsilon$ for all $0 \leq i \leq n$. Let $r_{n,\varepsilon}$ be the minimum cardinality of an (n, ε)-spanning set for f, and define the *topological entropy* of f to be

$$h(f) = \lim_{\varepsilon \to 0} \limsup_{n \to \infty} \frac{1}{n} \log r_{n,\varepsilon}.$$

We discuss the relationship between the entropy of f and the entropy of f^m, and we establish sufficient conditions for a set-valued function to have positive or infinite entropy. (Received September 09, 2014)

1106-37-954 **Michael Sylvester Keane*** (mkeane@wesleyan.edu), 307 Lakeridge Dr, San Antonio, TX 78229-3604. *Topological Conjugacy of Constant Length Substitution Dynamical Systems.*

Primitive constant length substitutions generate minimal symbolic dynamical systems. I intend to present in this lecture a survey of classification results of constant length substitution dynamical systems generated by primitive nonperiodic substitutions. Much of the material presented will be based on joint work with a number of co-authors: Ethan M. Coven, F.M. Dekking, Andrew Dykstra, Michelle Lemasurier. As an example of a perhaps interesting new result, we have proven that (if counted correctly) there are twelve primitive injective length two substitutions, among which are two on six symbols, which are conjugate to the Thue-Morse minimal system, and no more of this type. (Received September 09, 2014)

1106-37-963 **Mrinal Kanti Roychowdhury** and **Nina Snigireva*** (nina.snigireva@ucd.ie), School of Mathematical Sciences, University College Dublin, Dublin, Ireland. *Asymptotic of the geometric mean error in the quantization of recurrent self-similar measures.*

In this talk we will disscuss the quantization dimension $D(\mu)$ of a recurrent self-similar measure μ with respect to the geometric mean error. In particular, we will show that $D(\mu)$ coincides with the Hausdorff dimension $\dim_{\mathrm{H}}^*(\mu)$ of μ. In addition, we will prove that the $D(\mu)$-dimensional lower and upper quantization coefficients for μ are finite and positive. This is joint work with Mrinal Kanti Roychowdhury. (Received September 09, 2014)

1106-37-1032 **Nikita Selinger*** (nikita@math.sunysb.edu), Stony Brook University, Stony Brook, NY 11794. *Classification of Thurston maps with parabolic orbifolds.*

In a joint work with M. Yampolsky, we give a classification of Thurston maps with parabolic orbifolds based on our previous results on characterization of canonical Thurston obstructions. The obtained results yield a partial solution to the problem of algorithmically checking combinatorial equivalence of two Thurston maps. (Received September 09, 2014)

1106-37-1040 **Joanna Furno*** (jfurno@wesleyan.edu). *A measure-preserving transformation on the p-adic numbers.*

For a fixed prime p, the p-adic numbers are a locally compact group with an infinite Haar measure. We give a piecewise definition of an invertible transformation on $\mathbb{Q}_p$ that preserves Haar measure. The transformation also has a description as a Kakutani skyscraper, where the towers fit naturally into the spheres of $\mathbb{Q}_p$. We describe the topological and ergodic properties of this transformation. (Received September 09, 2014)

1106-37-1117 **Gregory A Varner*** (gvarner@jbu.edu), 2000 West University Street, Siloam Springs, AR 72761. *Existence and Uniqueness of Time-Invariant Measure for the Time-Dependent Navier-Stokes Equations.*

We will discuss recent results on the existence and uniqueness of time-invariant measure for the time-dependent two-dimensional Navier-Stokes equations on the sphere under a random kick-force. In particular, the necessary conditions for the existence and uniqueness of the measure for the kick-force model are presented for the time-periodic equations. Furthermore, a complete description of the support of the invariant measure is given in general and in several special cases. Extending the result to the general time-independent equations will also be discussed. (Received September 10, 2014)

1106-37-1121 **Sonja Stimac*** (sonja@math.hr). *Horseshoe-like maps of plane and symbolic dynamics.* Preliminary report.

I will present a possible approach to coding of attractors of horseshoe-like maps of plane (such as the Hénon and Lozi maps). I will also discuss some techniques which can be used if an attractor is characterized by an appropriate countable collection of sequences of 0s and 1s (which play role of “kneading sequences” of “critical points”). (Received September 10, 2014)

1106-37-1197 **Eric Bedford*** (ebedford@math.sunysb.edu), Department of Mathematics, Stony Brook University, Stony Brook, NY 11794. *Automorphisms of blowups of projective space.* Preliminary report.

We will discuss the existence of automorphisms and pseudo-automorphisms of complex manifolds with positive entropy. (Received September 11, 2014)

1106-37-1236 **Vaughn Climenhaga*** (climenha@math.uh.edu), **Todd Fisher** and **Daniel J Thompson**. *Unique equilibrium states for some robustly transitive systems.*

Examples of robustly transitive systems that are not uniformly hyperbolic were given by Mañé, and later by Bonatti and Viana. Recently it has been shown by Buzzi, Fisher, Sambarino, and Vásquez that these examples have unique measures of maximal entropy. We show that for a certain class of Hölder continuous potential functions these systems have unique equilibrium states. This class includes the geometric potentials and yields the SRB measure as an equilibrium state for these systems. The techniques are quite general and have applications to other classes of non-uniformly hyperbolic systems. (Received September 11, 2014)

1106-37-1299 **Kimberly D. Ayers*** (kdayers@iastate.edu). *Graph Determined Symbolic Dynamics and Hybrid Systems.*

In this research we explore the concept of symbolic dynamical systems whose structure is determined by a directed graph, and then discrete-continuous hybrid systems that arise from such dynamical systems. Typically, symbolic dynamics involve the study of a left shift of a bi-infinite sequence. We examine the case when the bi-infinite system is dictated by a graph; that is, the sequence is a bi-infinite path of a directed graph. We then use the concept to study a system of dynamical systems all on the same compact space M, where “switching” between the systems occurs as given by the bi-infinite sequence in question. The concepts of limit sets, chain recurrent sets, chaos, and Morse sets for these systems are explored. (Received September 12, 2014)

1106-37-1304 **Per Sebastian Skardal*** (skardals@gmail.com), Department of Math and Comp Sci, Universitat Rovira i Virgili, Avinguda Paisos Catalans 26, 43007 Tarragona, Tarragona, Spain. *Optimal synchronization of complex networks.*

Optimization of network synchronization is an important problem with applications to physics, biology, and engineering. In this talk I will consider networks of heterogeneous phase oscillators and derive a synchrony alignment function that can be readily optimized. I will demonstrate its utility with two examples: allocation of oscillators on a network and design of a network given a set of oscillators. In general synchronization is promoted by a strong alignment between the oscillators' frequencies and the dominant Laplacian eigenvectors. Optimized networks tend to have positive correlations between degrees and frequencies but negative correlations between neighboring frequencies. Interestingly, structural and dynamical heterogeneity complement one another: a more (less) heterogeneous network better synchronizes a more (less) heterogeneous set of oscillators.

I will complement these theoretical results with experiments of network-coupled electronic Rössler circuits tuned to the chaotic regime. Using this experimental setup, I will show that the mechanisms that promote synchronization in networks of phase oscillators extend to networks of chaotic oscillators.

P. S. Skardal, D. Taylor, and J. Sun, Phys. Rev. Lett., In press, arxiv:1402.7337. (Received September 12, 2014)

1106-37-1375 **Jesse D Feller*** (jdfeller@uwm.edu), 2666 N Humboldt Blvd #12, Milwaukee, WI 53212.
Random Iteration of Rational Maps.

Abstract: In this presentation, we will take a look at iteration of rational functions when the parameters of the function vary with each composition. This gives rise to what is known as Random Iteration when the sequence of parameters are random variables. Given a $z \in \overline{\mathbb{C}}$ we can examine the probability $\mathcal{P}(z)$ that z tends towards a neighborhood of a given attracting cycle. An early result in this area says that under certain conditions, these probabilities $\mathcal{P}(z)$ are continuous in z. Furthermore, each $z \in \overline{\mathbb{C}}$ will converge towards some attracting cycle with probability one. Our main result is a generalization of this idea. (Received September 12, 2014)

1106-37-1407 **Kyounghee Kim*** (kim@math.fsu.edu). *Pseudo-automorphisms of Blowup of Projective space along a set of points.* Preliminary report.

Let X be a blowup of $\mathbb{P}^n$ along a finite set of points. We will discuss connection between certain pseudo-automorphisms on X and elements of generalized Weyl group $W(p, q, r)$. (Received September 12, 2014)

1106-37-1408 **Nandor J Simanyi*** (simanyi@uab.edu), Campbell Hall, 1300 University Boulevard, Birmingham, AL 35294-1170. *Wojtkowski's Falling Balls Revisited.* Preliminary report.

In around 1990 M. P. Wojtkowski introduced the following intrigueing Haniltonian dynamical system: He considered the system of n (≥ 2) point masses $m_1, \dots, m_n$ falling freely in the vertical half line $\{q|\, q \geq 0\}$ (so that $0 \leq q_1 \leq q_2 \leq \dots \leq q_n$) under constant gravitation and colliding with each other and the solid floor $q = 0$ elastically. In order to have a natural, invariant symplectic cone system, we asume that $m_1 \geq \dots \geq m_n$ (i. e. the masses do not increase as we go up), but not all masses are equal. One is interested the ergodic properties, like hyperbolicity, ergodicity, mixing, etc of such systems. We survey the existing results, pose some challenging open questions, and sketch a roadmap for proving ergodicity of such systems with $m_1 > m_2$. (Received September 12, 2014)

1106-37-1447 **Eugen Andrei Ghenciu*** (ghenciue@uwstout.edu), **Mario Roy** and **Sara Munday**.
Nearest Integer Continued Fraction Systems. Preliminary report.

We introduce the nearest integer continued fraction expansions and we associate a generalized iterated function system to these expansions. The largest standard conformal iterated function subsystem turns out to have full Hausdorff dimension spectrum. We ask the same question for the entire system. (Received September 13, 2014)

1106-37-1450 **Zhizhen Zhao*** (jzhao@cims.nyu.edu), Courant Institute of Mathematical Sciences, New York University, 251 Mercer Street, New York, NY 10012, and **Dimitris Giannakis** (dimitris@cims.nyu.edu), Courant Institute of Mathematical Sciences, New York University, 251 Mercer Street, New York, NY 10012. *Analog Forecasting with Dynamics-Adapted Kernels.* Preliminary report.

We introduce a suite of forecasting methods which improve traditional analog forecasting (Lorenz, 1969) by combining ideas from state-space reconstruction in dynamical systems and kernel methods developed in harmonic analysis and machine learning. The first improvement is using Taken's delay-coordinate maps to recover information in the initial data lost through partial observations. Then weighted ensembles of analogs are chosen according to similarity kernel in delay-coordinate space featuring an explicit dependence on the dynamical vector field generating the data. The eigenvalues and eigenfunctions of such kernels define diffusion coordinates and a diffusion distance on the data manifold, giving better estimation of the nearest neighbors than Euclidean distance, especially in noisy observation environments. As a result, forecasts based on the kernel-weighted ensembles have significantly higher accuracy than the conventional approach. We include several approaches for constructing the kernel weighted forecast and illustrate these techniques in applications to forecasting in a low-order deterministic model for atmospheric dynamics with chaotic metastability, and interannual-scale forecasting in the North Pacific sector of a comprehensive climate model and observations. (Received September 13, 2014)

1106-37-1483 **Tom Sharland*** (tjshar@math.sunysb.edu). *Matings of cubic polynomials with a fixed critical point.*

We investigate the matings of pairs of cubic polynomials which have a fixed critical point. We will show that the only possible obstructions are Levy cycles. We will discuss similarities with the quadratic case and provide a simple condition under which the matings are obstructed. (Received September 13, 2014)

1106-37-1511 **Sergey Bezuglyi*** (bezuglyi@gmail.com), 735 20th Ave apt.4, Coralville, IA 52241.
Subdiagrams and invariant measures on Bratteli diagrams.

The concept of a Bratteli diagram, that was originally defined in the theory of operator algebras, is now a powerful tool for the study of dynamical systems. The problem of finding all ergodic invariant measures and their supports for a homeomorphism of a compact metric space is one that belongs to the core of topological dynamics. This problem becomes more transparent in Cantor dynamics because any aperiodic homeomorphism T admits a realization as a Vershik homeomorphism acting on the path space X_B of a Bratteli diagram B. We are going to discuss and answer the following questions in the talk:

- Given a subdiagram B' of B and an ergodic measure μ on X_B, determine conditions on B' such that the subset $X_{B'}$ has positive measure μ.

- Let a measures ν be extended from $X_{B'}$ to $\mathcal{R}(X_{B'})$ by invariance with respect to the tail equivalence relation $\mathcal{R}$. Under what conditions is $\nu(\mathcal{E}(X_{B'}))$ finite (infinite)?

- A finite rank k diagram B can support at most k ergodic (finite and infinite) measures. Is it possible to determine which properties of incidence matrices of B would guarantee the existence of exactly k ergodic measures? (Received September 13, 2014)

1106-37-1544 **Takao Namiki*** (`nami@math.sci.hokudai.ac.jp`), Kita 10 Nishi 8, Sapporo, Hokkaido 060-0810, Japan. *On quantum walks driven by chaotic dynamical system.*

In the presentation the author will give quantum walks driven by chaotic dynamical system and show that the quantum walks have the same statistical property as the classical random walk and Markov chain have. The chaotic dynamical systems which appear in the quantum walk are typical example of uniformly hyperbolic dynamical system with invariant probability measure. Moreover, two examples of semi-classical approximation on the quantum walk will be given. These examples are obtained from two types of quantization of dynamical system. (Received September 14, 2014)

1106-37-1630 **Rich L Stankewitz*** (`rstankewitz@bsu.edu`), Dept. of Mathematical Sciences, Ball State University, Muncie, IN 47306, and **Sumi Hiroki** (`sumi@math.sci.osaka-u.ac.jp`), Department of Mathematics, Graduate School of Science, Osaka University, Osaka, Japan. *Drawing Julia sets of Rational Semigroups.*

We consider methods for extending the Julia set drawing algorithms for the iteration case to the more general setting of rational semigroups. These methods include (i) the (complement of) an attracting basin algorithm, (ii) the full backward orbit algorithm, and (iii) the random backward iteration algorithm. Method (iii) has recently been proven to be valid for rational semigroups (of a certain type), so its proof will also be discussed. (Received September 14, 2014)

1106-37-1686 **Ben Hayes*** (`benjamin.r.hayes@vanderbilt.edu`). *Metric Mean Dimension for Algebraic Actions of Sofic Groups.*

Mean dimension and metric mean dimension are dynamical invariants of an action of a group on a compact metrizable space. They were defined for the case when the group is amenable by Lindenstrauss and Weiss, and has been extended to the sofic case by Li. Metric mean dimension can be thought of as a dynamically version of dimension, and is an analogue of entropy for "large" spaces. For example, the metric mean dimension of a Bernoulli shift is the dimension of the base. In this work, we are concerned with metric mean dimension in the case of alegbraic actions which are actions of a group Γ by automorphisms on a compact, metrizable, abelian group X. When Γ is sofic, we relate the metric mean dimension of X to a quantity called the von Neumann-Lück rank of the dual of X. The von Neumann-Lück rank of a $\mathbb{Z}(\Gamma)$-module A may be regarded as the von Neumann dimension of a certain Hilbert space representation associated to A. This work is a partial generalization of results due to Li-Liang in the amenable case, and is part of several instances in which invariants of algebraic actions are related to L^2-invariants of $\mathbb{Z}(\Gamma)$ modules. (Received September 15, 2014)

1106-37-1691 **Peter R Massopust*** (`massopust@ma.tum.de`), Centre of Mathematics, Research Unit M6, Boltzmannstr. 3, 85747 Garching b. Munich, Germany. *Self-Referential Descriptions of Analytic Functions.*

We consider the representation of polynomials and analytic functions using analytic iterated function systems, and the consequences of these representations in numerical analysis. (This is joint work with Michael F. Barnsley and Markus Hegland.) (Received September 15, 2014)

1106-37-1705 **Su Gao*** (`sgao@unt.edu`), Department of Mathematics, 1155 Union Circle #311430, Denton, TX 76203, and **Aaron Hill**. *Bounded Rank-One Transformations.*

We define the notion of canonical boundedness among rank-one transformations and use it to characterize the class of all bounded rank-one transformations with trivial centralizer. We also explicitly characterize totally ergodic rank-one transformations with bounded cutting parameter. Together with a recent result of Ryzhikov our results provide a simple procedure for determining whether a bounded rank-one transformation has minimal self-joinings of all orders purely in terms of the cutting and spacer parameters for the transformation. (Received September 15, 2014)

1106-37-1779 **Carl P Dettmann*** (carl.dettmann@bristol.ac.uk). *Degrees of stickiness in mushroom billiards.*

Billiards are dynamical systems in which a point particle moves uniformly in a specified region except for mirror-like reflections from the boundary. Dynamical properties depend on the geometry, and provide a large variety of illustrative examples of Hamiltonian dynamics, as well as inspiration for physical experiments. Mushroom billiards were introduced by Bunimovich in 2001 as an example of sharply divided (regular and chaotic) phase space. Later, Altmann et al pointed out that almost all mushrooms have parabolic orbits in the chaotic region leading to "stickiness," algebraic slowing of the chaotic expansion and mixing properties. A zero measure set of mushroom parameters for which these orbits are absent, and the remaining stickiness, originating from the boundary of the chaotic region itself, will be characterised using Diophantine approximation methods. The results may shed light on stickiness in general Hamiltonian systems with mixed phase space. (Received September 15, 2014)

1106-37-1852 **Aditya Dhumuntarao*** (adhumunt@gmail.com), School of Mathematical and Statistical, Sciences, PSA 837, Tempe, AZ 85287, and **Wenbo Tang**. *Bistability in Inhomogeneity — Effects of Flow Coherent Structures on the Fate of a Bi-stable Reaction.*

A numerical study on the mixing process of a chemical reaction model between two stable states adjacent to each other in water is presented. The two stable states are equilibriums and are homogenized by fluid stirring and diffusion, and settle into a single stable state. With all other parameters fixed, we find the dependence of the final state on the reacting speed. Interestingly, with the existence of coherent structures, at a range of intermediate speeds, the final state also depends on the flow topology. The exact dependence on flow topology is explored in detail. For this bistable reaction, the elliptic flow structures help maintain scalar concentration and preserve the small impurity. These results attribute to the fundamental connection between the underlying flow topology and the domain transitions of dynamic biogeochemical processes. (Received September 15, 2014)

1106-37-1927 **Benjamin N Wilson*** (wilsonbn@email.unc.edu) and **Karl Petersen**. *Measuring Complexity and Structure in Dynamical Systems.*

In 1994, neuroscientists Edelman, Sporns, and Tononi proposed a quantitative measure of complexity or interconnectivity of neural networks called neural complexity. In 2012, Buzzi and Zambotti studied it in the setting of probability for families of random variables and generalized neural complexity to a measurement called intricacy. We will describe a way to measure the complexity and structure of a dynamical system based on these concepts, compare these measurements to the usual measure-theoretic and topological entropies, give some properties of these quantities, and look at some questions that they raise. (Received September 15, 2014)

1106-37-1928 **William Yessen***, yessen@rice.edu. *Applications of polynomial dynamics to spectral theory of aperiodic infinite Jacobi matrices.*

Aperiodic Jacobi operators, arising in the study of the physics of quasicrystals, have been widely studied for the past thirty years. A well-developed technique for studying the (topological structure of the) spectrum of such operators relies on dynamical properties (Axiom A, partial hyperbolicity, and other) of a certain class of polynomial maps, called the trace maps. We shall present this technique in a general context, as well as some classical and recent results obtained by application of this technique. We shall also state a few open problems of modern interest that relate not only to spectral theory of the aforementioned operators, but also to some questions in holomorphic dynamics. (Received September 15, 2014)

1106-37-1964 **Giulio Tiozzo*** (giulio.tiozzo@yale.edu), 10 Hillhouse Avenue, New Haven, CT 06511. *Continuity of core entropy of quadratic polynomials.*

The core entropy of polynomials, recently introduced by W. Thurston, is a dynamical invariant which can be defined purely in combinatorial terms, and provides a useful tool to study parameter spaces of polynomials. The theory of core entropy extends to complex polynomials the entropy theory for real unimodal maps: the real segment is replaced by an invariant tree, known as Hubbard tree, which lives inside the filled Julia set. We prove that the core entropy of quadratic polynomials varies continuously as a function of the external angle, answering a question of Thurston. (Received September 15, 2014)

1106-37-2163 **Sahana Vasudevan*** (svasudevan@college.harvard.edu), svasudevan@college.harvard.edu. *Rank-one homeomorphisms of* $\mathbb{T}^2$*.*

We give an explicit rank-one construction for some homeomorphisms of $\mathbb{T}^2$ of the form $T(x,y) = (x+h(y), y+\alpha)$ for certain irrational $\alpha \in [0,1)$. We discuss spectral properties of such transformations and compare with existing examples. (Received September 16, 2014)

1106-37-2174 **Alex Wright*** (amwright@stanford.edu). *From rational billiards to dynamics on moduli spaces.*

Consider a billiard ball bouncing around in a polygon. This simple system demonstrates remarkable complexity–for example, it is an open problem to prove that there is a periodic billiard trajectory in every polygon. However, if the angles are all rational multiples of π, a great deal is known. This is because such a polygon can be "unfolded" to give a surface with extra structure, and there is an $SL(2,\mathbb{R})$ action on the space of all such surfaces. We will explain the relevance of this action, and state a recent result of Eskin, Mirzakhani and Mohammadi, which gives that the closure of every $SL(2,\mathbb{R})$ orbit is a manifold. We will explain how this result was inspired by results on homogeneous spaces. (Received September 16, 2014)

1106-37-2215 **Volodymyr Kondratenko*** (volodymyr.kondratenko@ucdenver.edu), University of Colorado Denver, Academic Building 1, 1201 Larimer Street, Apt. #4126, Denver, CO 80222, and **Jan Mandel** (jan.mandel@gmail.com). *Efficient Algorithms with an application to Wildland Fire Simulation.*

In this work, we develop the multiple-source shortest path algorithms that use a given set of points (called a perimeter) as a source. This technique has a high application value in such problems as fire propagation modeling, epidemiology, demographics control, etc. Different algorithms were developed in order to suit possible demands of the user, such as implementation in parallel programming, minimization of the amount of iterations and memory, and use of the rate of spread (weights of the constituent edges) as a time dependent variable. The new methods were implemented in the Weather Research Forecasting (WRF) model coupled with the fire spread code SFIRE, where it solves the problem of the misbalance of fire and atmospheric state development, which happens when the model assimilates to the new data. This method was applied to a real fire case study. (Received September 16, 2014)

1106-37-2239 **Joshua P Bowman*** (joshua.bowman@gmail.com). *Chebyshev-like maps via Newton's identities.* Preliminary report.

The classical Chebyshev polynomials were extended to two-dimensional maps by Koornwinder, Dunn–Lidl, and others, and then to all dimensions by Veselov and Hoffman–Withers using the theory of root systems. We give a more general and simplified framework for these constructions using families of commuting endomorphisms of the algebra of polynomials on $\mathbb{C}^n$. A key element is the relationship between symmetric power sums and elementary symmetric polynomials, proved by Girard and Newton and commonly called Newton's identities. As a consequence, we are able to characterize families of maps of $\mathbb{C}^n$ that are semiconjugate to power maps. This is joint work with Corey Manack. (Received September 16, 2014)

1106-37-2268 **Erin Farrell Denette*** (ekfarrell@my.uri.edu) and **Araceli Medina-Bonifant** (bonifant@math.uri.edu). *The Construction of a Non-Uniquely Ergodic Minimal Cantor Set.*

Let $f : X \to X$ be a minimal Cantor set. Gambaudo & Martens (2006) showed that f can be represented as the projective limit of directed graphs and gave conditions under which it can be guaranteed that f is uniquely ergodic. We will use the theory behind this projective limit representation to introduce the construction of a minimal Cantor set that is not uniquely ergodic. (Received September 16, 2014)

1106-37-2282 **Jan P. Boroński** (boronski@osu.cz), National Supercomputing Centre IT4Innovations, Division of the University of Ostrava, 30. dubna 22, 70103 Ostrava, Czech Rep, and **Piotr Oprocha*** (oprocha@agh.edu.pl), AGH University of Science and Technology, Faculty of Applied Mathematics, al. Mickiewicza 30, 30-059 Kraków, Poland. *Inverse limits and attractors in dimension 2.*

In 1990 Barge and Martin presented a method of construction of global attractors of planar homeomorphisms in terms of inverse limits. This technique can also be extended to obtain attractors arising as inverse limits of degree one map of the circle. That way we can obtain attractors with very strange topological structure, such as pseudoarc or pseudocircle.

In this talk we are going to present recent results obtained jointly with Jan Boroński. Among other things, we are going to explain how to obtain a pseudocircle as an attractor of map on a tori with a nonunique rotation vector on it. While it does not solve Franks-Misiurewicz Conjecture, it provides a new method of construction of such attractors. (Received September 16, 2014)

1106-37-2335 **Abdul-Rehman Kashif*** (kashmology@gmail.com), University of Ha'il, Department of Mathematics, Ha'il, Saudi Arabia, and **Muhammad Shoaib**. *Regions of central configurations in a 4+1-body problem.*

A central configuration for n-body problem occurs when the position vector of each particle with respect to the center of mass is a common scalar multiple of its acceleration. We study the central configuration of a symmetric 4+1-body problem where four of the masses are placed at the vertices of a rhombus and the fifth mass can take various positions on the y-axis which is the axis of symmetry. We classify regions in the phase space where it is possible to choose positive masses (or ratio of positive masses) which will make the configuration central. Central configurations are not possible in the compliment of the above said region. We will also comment on the finiteness of central configurations of this particular set-up. (Received September 16, 2014)

1106-37-2343 **Farrah Sadre-Marandi*** (sadre@math.colostate.edu), Department of Mathematics, 1874 Campus Delivery, Fort Collins, CO 80523-1874. *A Kinetic Model for HIV-1 Viral Capsid Nucleation.* Preliminary report.

The viral capsid acts as a protective shell for the genetic material (DNA or RNA) of virus. Viral capsid assembly goes through two stages during maturation: nucleation and elongation. After maturation, a virus is able to attack new host cells and replicate its DNA or RNA, leading to virus spread throughout the host body. Therefore, it is of great interest to characterize favorable, restrictive, and prohibitive conditions for viral capsid assembly so that antiviral therapies can be developed. This talk presents a mathematical model developed specifically for the nucleation of HIV-1 capsid. Numerical simulations of HIV-1 capsid nucleation are conducted using a 6-species dynamical system model. Deterministic and stochastic factors in this process will be examined as well as the sensitivity of the system behavior to model parameters. This research was funded by an NSF EAPSI award during the speaker's visit to study under Dr. Xiufen Zou at Wuhan University in China. (Received September 16, 2014)

1106-37-2345 **Kenneth Scott Jacobs***, 1023 D. W. Brooks Drive, Department of Mathematics, UGA, Athens, GA 30605. *An Equidistribution Result in Non-Archimedean Dynamics.*

Let K be a complete, algebraically closed, non-Archimedean valued field, and let $\phi \in K(z)$ with $\deg(\phi) \geq 2$. In two recent articles, R. Rumely introduced the function $\mathrm{ordRes}_\phi(x)$ on the Berkovich line and a canonical probability measure ν_ϕ (the crucial measure) supported on the interior of the Berkovich line. What can be said of the convergence of the corresponding objects attached to the iterates of ϕ? We answer this question by showing that, suitably normalized, the functions $\mathrm{ordRes}_{\phi^n}(x)$ converge to the diagonal values of the Arakelov-Green's function $g_\phi(x, x)$, and that the measures ν_{ϕ^n} equidistribute to the invariant measure μ_ϕ. (Received September 16, 2014)

1106-37-2380 **Scott Sutherland*** (scott@math.sunysb.edu), Department of Mathematics, Stony Brook University, Stony Brook, NY 11794. *On the measure of the Feigenbaum Julia set.* Preliminary report.

We discuss a computer-assisted proof that the Julia set of the limit of period-doubling renormalization in the quadratic family has zero measure. This is joint work with Artem Dudko. (Received September 16, 2014)

1106-37-2408 **Joe Adams*** (jdfadams@math.sunysb.edu). *A priori bounds for infinitely primitively renormalizable polynomials of bounded type.* Preliminary report.

Given a polynomial admitting an infinite sequence of primitive renormalizations of bounded type around one of its critical points, we derive unbranched a priori bounds around that critical point. If time permits, we will discuss applications of these a priori bounds. (Received September 16, 2014)

1106-37-2423 **Volodymyr Nekrashevych*** (nekrash@math.tamu.edu). *Finitely presented groups associated with expanding maps.*

We associate with every expanding self-covering of a compact metric space a finitely presented group. We show that if the space is path connected, then this group classifies the dynamical system: two groups are isomorphic as abstract groups if and only if the dynamical systems are topologically conjugate. We also show that these groups have simple commutator subgroup and compute the abelianization. (Received September 16, 2014)

1106-37-2580 **Will Brian**, **Jonathan Meddaugh** and **Brian E Raines*** (brian_raines@baylor.edu).
Chain Transitivity and Variations of the Shadowing Property.

We show that, under the assumption of chain transitivity, the shadowing property is equivalent to the thick shadowing property. (Received September 16, 2014)

1106-37-2585 **Dominik Kwietniak*** (dominik.kwietniak@uj.edu.pl), Instytut Matematyki UJ, ul. Loajsiewicza 6, 30-348 Krakow, Poland. *On intrinsic ergodicity of subordinate and almost specified shift spaces.*

A shift space is intrinsically ergodic if it posseses a unique measure of maximal entropy. Bowen introduced the specification property and proved that the shift spaces with the specification property are intrinsically ergodic. Pfister and Sullivan generalized Bowen's notion and defined the g almost product property, later coined the almost specification property by Thompson. It was an open question whether every almost specified shift space is intrinsically ergodic. I am going to present the example showing that the answer is negative, along with some other results about almost specified dynamical systems. The talk is based on a joint work with Piotr Oprocha (AGH Kraków) and Michał Rams (IM PAN Warszawa). (Received September 16, 2014)

1106-37-2586 **Jonathan Meddaugh*** (jonathan_meddaugh@baylor.edu), Department of Mathematics, Baylor University, One Bear Place #97328, Waco, TX 76798, and **Brian Raines**.
Shadowing, ω-limit sets and internal chain transitivity.

A function f on a compact metric space X exhibits shadowing provided that for every $\epsilon > 0$ there exists a $\delta > 0$ such that for every sequence $\langle x_i \rangle$ in X satisfying $d(x_{i+1}, f(x_i)) < \delta$ there exists a point z in X with $d(x_i, f^i(z)) < \epsilon$. In other words, approximate orbits are themselves approximated by true orbits.

In this talk we will discuss the the shadowing property in the context of characterizing ω-limit sets for f. Specifically, we show that if f has shadowing, the closure of the collection of ω-limit sets of f is exactly the set of internally chain transitive sets. As a consequence, we have a characterization of the collection of ω-limit sets in a variety of classes of maps, including maps on the interval, maps on finite graphs, and maps on certain quadratic Julia sets. (Received September 16, 2014)

1106-37-2590 **Milan Stehlik*** (mlnstehlik@gmail.com), Casilla 110-V, Valparaíso, Chile. *Fractal dimension in abstract spaces.*

When we consider fractal based cancer diagnostic, many times a statistical procedure to assess the fractal dimension is needed. We shall look for some analytical tools for discrimination between cancer and healthy ranges of fractal dimensions of tissues (see [1], [2]). The algebraic and topologic properties are available via appropriate set structure, e.g. bornology (see [3,4]). The theory of lattice-valued bornological vector systems, which has been started in [4], makes another step towards development of a new technique for cancer research. Having a place for both geometric and algebraic information, bornological systems seem to us to be more suitable.

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1106-37-2610 **Terrence M Adams** and **Cesar E Silva*** (csilva@williams.edu), Department of Mathematics and Statistics, Williams College, Williamstown, MA 01267. *Rank-one transformations of ergodic index k in infinite measure.*

In 1963, Kakutani and Parry constructed, for each positive integer k, infinite measure-preserving countable state Markov shifts T such that the k-fold product of T with itself is ergodic but the $k + 11$-fold product is not conservative, hence not ergodic. We construct infinite measure-preserving rank-one transformations T such that the k-fold product of T with itself is ergodic but the $k+1$ product is conservative but not ergodic. Our examples are also rigid and of a different nature than Markov shifts. (Received September 16, 2014)

1106-37-2615 **Julien Clancy** (julien.clancy@yale.edu), **Rina Siller Friedberg*** (rinafriedberg@uchicago.edu), **Indraneel Kasmalkar** (indraneelk@berkeley.edu), **Isaac Loh** (il2@williams.edu), **Tudor Padurariu** (tudor_pad@yahoo.com), **Cesar E Silva** (csilva@williams.edu) and **Sahana Vasudevan**. *Conservativity of Products in Infinite-Measure.* Preliminary report.

The properties of infinite measure-preserving rank-one transformations have proven to be very different from those of finite rank-one transformations, where the behavior of products is well understood. Adams, Friedman and Silva have constructed rank-one (hence ergodic) infinite measure-preserving transformations T such that $T \times T$ is not conservative (or recurrent). In this talk, we prove that for all rank-one transformations T, the product $T \times T^{-1}$ is always conservative, using the notion of descendants in constructing rank-one transformations, along with probabilistic methods. We also show that the situation is different in countable state Markov shifts. (Received September 16, 2014)

1106-37-2638 **Araceli Bonifant*** (bonifant@math.uri.edu), **Xavier Buff** (xavier.buff@math.univ-toulouse.fr) and **John Milnor** (jack@math.sunysb.edu). *Fjords in a Parameter Space for Antipode Preserving Cubic Maps.*

This talk will describe the topological properties of the "fjords" that appear in the parameter space for antipode preserving cubic maps with a critical fixed point. (Received September 16, 2014)

1106-37-2659 **Charles Lamb*** (clamb@iup.edu) and **Erik S. Van Vleck**. *Bifurcation Analysis of Systems of Neutral Equations of Mixed Type.* Preliminary report.

We consider a system of neutral equations of mixed type generalizing a parallel nerve fiber model previously considered. A bifurcation analysis of the system is presented. Analytically, the bifurcation equation is obtained via the Lyapunov-Schmidt method. The kernel of the associated linear operator is shown to be one-dimensional, and a saddle-node bifurcation occurs as the equations couple. Numerically, we employ a pseudo-spectral approach within a path following framework to continue solutions. (Received September 16, 2014)

1106-37-2708 **Igors Gorbovickis*** (igors.gorbovickis@utoronto.ca). *Parameterizing degree n rational maps by multipliers of periodic orbits.*

It was suggested by John Milnor to use the multipliers of the fixed points to parameterize the moduli space of degree 2 rational maps of the Riemann sphere. In this talk we will discus an attempt to use multipliers of periodic orbits as the parameters on the moduli space of degree n polynomial or rational maps. We will show that at its generic point, the moduli space of degree n polynomial maps can be locally parameterized by the multipliers of $n-1$ arbitrary distinct periodic orbits. This is equivalent to the statement that these multipliers considered as algebraic functions on the moduli space, are algebraically independent over $\mathbb{C}$. Further, we will discuss a generalization of the above result to the case of degree n rational maps. (Received September 16, 2014)

1106-37-2750 **Julien E Clancy*** (julien.clancy@yale.edu), 367 Elm Street Apt. 402, New Haven, CT 06511, and **Rina Friedberg**, **Indraneel Kasmalkar**, **Isaac Loh**, **Tudor Pădurariu**, **Cesar Silva** and **Sahana Vasudevan**. *On the Ergodicity of Products of Transformations in Infinite Measure.*

Weak mixing for finite measure-preserving transformations has many interesting equivalent characterizations, among which is that $T \times T$ is ergodic. This in particular implies that $T \times T^{-1}$ must be ergodic. It has been known for some time that many of these characterizations do not remain equivalent in the infinite measure-preserving case. In this talk we will construct infinite measure-preserving rank one transformations such that $T \times T$ is ergodic but $T \times T^{-1}$ is not ergodic, and other related examples. This partially answers a question of Bergelson. The methods are combinatorial and probabilistic and use the notion of descendants in the constructions of the transformations. (Received September 16, 2014)

1106-37-2770 **Daniel Cuzzocreo*** (dcuzzocreo@smith.edu). *Parameter Space Structures for Rational Maps.*

For parametrized families of dynamical systems, a major goal is to understand the structure of the bifurcation locus in the parameter space. The family $F_\lambda = z^n + \lambda/z^d$ gives a 1-parameter, $n+d$ degree family of rational maps of the Riemann sphere, which arise as singular perturbations of the polynomial z^n. In this talk we describe some new results which explain some of the intricate fractal structure that arises in these parameter spaces, including a system of necklaces and subnecklaces converging down to the McMullen domain, passing alternately through superstable and escape-time Sierpiński parameters. (Received September 16, 2014)

1106-37-2789 **Remus Radu*** (rradu@math.sunysb.edu), Institute for Mathematical Sciences, Stony Brook University, Stony Brook, NY 11794-3660, and **Raluca Tanase** (rtanase@math.sunysb.edu), Institute for Mathematical Sciences, Stony Brook University, Stony Brook, NY 11794-3660. *Topological models for semi-parabolic Hénon maps.*

We give a characterization of the family of complex Hénon maps with a semi-parabolic fixed point that arise as small perturbations of a quadratic polynomial with a parabolic fixed point. We prove that the Hénon map has connected Julia set J which is homeomorphic to a quotiented solenoid. The Julia set J^+ is homeomorphic to a quotiented 3-sphere with a certain solenoid removed. We will explain where these maps sit in the whole parameter space of complex Hénon maps and explore other regions of connectivity, with similar properties. (Received September 16, 2014)

1106-37-2804 **Raluca Tanase*** (rtanase@math.sunysb.edu), Institute for Mathematical Sciences, Stony Brook University, Stony Brook, NY 11794-3660, and **Remus Radu** (rradu@math.sunysb.edu), Institute for Mathematical Sciences, Stony Brook University, Stony Brook, NY 11794-3660. *Continuity of Julia sets in $\mathbb{C}^2$.*

We discuss some continuity results for the Julia sets J and J^+ of a complex Hénon map $H_{c,a}(x,y) = (x^2 + c + ay, ax)$. We look at the parameter space $\mathcal{P}_{(1+t)\lambda} \subset \mathbb{C}^2$ of Hénon maps which have a fixed point with one eigenvalue $(1+t)\lambda$, where λ is a root of unity and t is real and sufficiently small. The Hénon map has a semi-parabolic fixed point when $t = 0$ and we use techniques that we have developed for the semi-parabolic case to describe nearby perturbations. We show that for $0 < |a| < \delta$ and $(c,a) \in \mathcal{P}_{(1+t)\lambda}$, the Julia sets J and J^+ depend continuously on the parameters as $t \to 0$. These results can be regarded as a two-dimensional analogue of radial convergence for polynomial Julia sets. (Received September 16, 2014)

1106-37-2824 **Jorge Luis Guerrero*** (agntp123@dusty.tamiu.edu), TX. *An Analogy of Li-Yorke's Period Three Implies Chaos for Simple Dendrites.* Preliminary report.

The Li-Yorke theorem outlines the basic requirements needed to make a function mapping from an arbitrary interval to itself under function iterations and ensure that the function is chaotic. The theorem states that as long as a continuous mapping f has a point $a \in I$ where I is an arbitrary interval, and $f^3(a) \leq a < f(a) < f^2(a)$ then for every period there exist a point with such period, and there is an uncountable set $S \subset I$ that contains no periodic points with the following,

(A) For every $p, q \in S$ with $p \neq q$,

$$\limsup_{n\to\infty} |f^n(p) - f^n(q)| > 0 \quad \text{and} \quad \liminf_{n\to\infty} |f^n(p) - f^n(q)| = 0$$

(B) For every $p \in S$ and periodic point $q \in I$,

$$\limsup_{n\to\infty} |f^n(p)f^n(q)| > 0$$

We will consider a simple dendrite which is a locally connected dendroid, having tree branches connected to a center point. A simple dendrite has similar properties to an interval, but a map of a branch may be mapped to a multiple branches. The analogy of the Li-Yorke theorem will be created for the simple dendrite and it will satisfy all of the requirements. A conjecture will also be given for other cases of the dendrites. (Received September 16, 2014)

1106-37-2831 **Lakshmi Roychowdhury*** (roychowdhuryl@utpa.edu), Dept of Mathematics, UTPA, 1201 West University Drive, Edinburg, TX 78539. *Optimal points for nonhomogeneous Cantor distributions.*

Let C be the Cantor set generated by the two mappings $S_1(x) = \frac{1}{4}x$ and $S_2(x) = \frac{1}{2}x + \frac{1}{2}$ on $\mathbb{R}$. Let P be the unique Borel probability measure on $\mathbb{R}$, where P is given by $P = \frac{1}{4}P \circ S_1^{-1} + \frac{3}{4}P \circ S_2^{-1}$. Then P has support the Cantor set C. For such a probability measure we have determined the n-optimal points and the nth quantization error for all $n \geq 1$. (Received September 16, 2014)

1106-37-2885 **Yaroslav Vorobets*** (yvorobet@math.tamu.edu), Department of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77843-3368. *The Grigorchuk groups and Toeplitz subshifts.*

The Grigorchuk groups are a family of 4-generated 2-groups of automorphisms of the binary rooted tree. The groups are not finitely presented but all relators of any particular group can be obtained from a finite set by successively applying certain substitutions depending on the group. The sequence of substitution rules gives rise to an infinite sequence over an alphabet of four letters which, in a sense, encodes the structure of the group.

We show that the sequence associated to any Grigorchuk group is a Toeplitz sequence. The corresponding subshift is an extension of the binary odometer which is one-to-one up to a countable set. Further, we establish a relation between the Grigorchuk group and the Toeplitz subshift as dynamical systems. (Received September 17, 2014)

39 ► Difference and functional equations

1106-39-83 **Johnny Henderson*** (johnny_henderson@baylor.edu), Department of Mathematics, Baylor University, Waco, TX 76798-7328, and **Rodica Luca** (rluca@math.tuiasi.ro), Department of Mathematics, Gh. Asachi Technical University, 700506 Iasi, Romania. *On a second order nonlinear discrete multipoint eigenvalue problem.*

We study the existence and non-existence of positive solutions of a system of nonlinear second order difference equations with eigenvalues subject to multipoint boundary conditions. (Received July 06, 2014)

1106-39-272 **qihua huang*** (qihua@ualberta.ca), Department of Mathematical & Statistical, Sciences, University of Alberta, Edmonton, Alberta T6G 2G1, Canada, and **mark a lewis** (mark.lewis@ualberta.ca), Department of Mathematical & Statistical, Sciences, University of Alberta, Edmonton, Alberta T6G 2G1, Canada. *Homing Fidelity and Reproductive Rate for Migratory Populations.*

Short-term and long-term population growth rates can differ considerably. While changes in growth rates can be driven by external factors, we consider another source for changes in growth rate. That is, changes are generated internally by gradual modification of population structure. Such a modification of population structure may take many generations, particularly when the populations are distributed spatially in heterogeneous environments. Here the net reproductive rate R_0 is not sufficient to characterize short-term growth. Indeed, a population with net reproductive rate greater than one could initially decline precipitously, or a population with net reproductive rate less than one could initially grow substantially. Thus we augment the net reproductive rate with lower and upper bounds for the transient reproductive rate, R_l and R_u. We apply these measures to the study of spatially structured salmon populations and show the effect of variable homing fidelity on short-term and long-term generational growth rates. (Received August 18, 2014)

1106-39-359 **Youssef Naim Raffoul*** (yraffoul1@udayton.edu), Department of Mathematics, 300 College park, Dayton, OH 45469-2316, and **Ernest Yankson**. *Existence Of Bounded Solutions For Almost Linear Volterra Difference Equations Using Fixed Point Theory and Lyapunov Functionals.*

We obtain sufficient conditions for the boundedness of solutions of the almost linear Volterra difference equation

$$\Delta x(n) = a(n)h(x(n)) + \sum_{k=0}^{n-1} c(n,k)g(x(k))$$

using Krasnoselskii's fixed point theorem. Also, we will display a Lyapunov functional that yield boundedness of solution and compare both methods.
(Received August 25, 2014)

1106-39-361 **Allan C Peterson*** (apeterson1@unl.edu), 6650 Blue Ridge Lane, Lincoln, NE 68516. *Boundary value problems for a self-adjoint Caputo nabla fractional equation.* Preliminary report.

We will be concerned with the nabla fractional calculus. We will introduce the self-adjoint Caputo nabla fractional equation. In particular, a study of boundary value problems for this Caputo self-adjoint equation will be given. (Received August 25, 2014)

1106-39-362 **E Cabral Balreira***, One Trinity Place, Department of Mathematics, San Antonio, TX 78212, and **Saber Elaydi** and **Rafael Luis**. *Geometry and Global Stability of Monotone Discrete Dynamical Systems.*

We develop a geometric generalization for the notion of competitive maps in higher dimensions. Namely, if $F : \Omega \to \mathbb{R}^+$ be a local diffeomorphism. We say that F is normally monotone at p if for any hypersurface γ of codimension one containing p with a positive normal vector $\eta_{\Gamma(p)}$ then its image under F is also positive. We call F normally monotone if it is so at every point. We show that this definitions is equivalent for known results for planar maps. The advantage is that using this geometric interpretation we are able to describe the basin of attraction for any orbit and a criteria for global stability whenever the map has an unique positive fixed point for higher dimensional maps. We provide analytic conditions to check for geometric monotonicity and illustrate our results with the Beverton-Holt and Ricker competition map. (Received August 25, 2014)

1106-39-363 **Ronald E. Mickens*** (rmickens@cau.edu), Clark Atlanta University, Physics Department, Atlanta, GA 30314. *Exact Finite Difference Schemes for the Cauchy-Euler Equation: Application to the Black-Sholes Equation.*

Consider the following Cauchy-Euler equation

$$x^2 y'' + bxy^{'} + cy = 0, \tag{1}$$

where (a, b, c) are constants. Observe that this is a linear, second-order differential equation, having the property of scale-invariance, i.e., under the transformation, $x \longrightarrow \lambda x$, the form of the equation does not change. Using its solutions, we construct an exact finite difference discretization for this ODE and use the result to then formulate several finite difference schemes for the Black-Shole equation[1)] of mathematical finance by means of the method of subequations.[2)]

References

1) Paul Wilmott et al., The Mathematics of Financial Derivatives (Cambridge University Press, New York, 1995); see Chapters 3 and 8.

2) R.E. Mickens, Nonstandard Finite Difference Models of Differential Equations (World Scientific, River Edge, NJ, 1994). (Received August 25, 2014)

1106-39-429 **Fatma Karakoc*** (fkarakoc@ankara.edu.tr), Ankara University, Faculty of Sciences, Department of Mathematics, Tandogan, 06100 Ankara, Turkey, and **Huseyin Bereketoglu**. *Asymptotic Constancy for Pantograph Equations with Impulses.*

It is known that pantograph equations are emerged in the mathematical model of electrified railway systems. In this talk, we consider a system of pantograph equations with impulses. Sufficient conditions for the convergence of solutions are obtained. Moreover, by using the solution of an integral equation a formula is given for the limit of the solutions as $t \to \infty$. (Received August 28, 2014)

1106-39-435 **Raegan Higgins** (raegan.higgins@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409, **Candace M Kent** (cmkent@vcu.edu), Department of Mathematics, Virginia Commonwealth University, Richmond, VA 23284, **Vlajko L Kocic*** (vkocic@xula.edu), Mathematics Department, Xavier University of Louisiana, New Orleans, LA 70125, and **Yevgeniy Kostrov** (ykostrov@xula.edu), Mathematics Department, Xavier University of Louisiana, New Orleans, LA 70125. *Dynamics of a nonlinear discontinuous difference equation.* Preliminary report.

In this paper we study the global asymptotic behavior, oscillation, and a periodicity of a discontinuous difference equation

$$x_{n+1} = F(x_n), \quad n = 0, 1, ..., \tag{1}$$

where $x_0 > 0$ and function F satisfies the following hypotheses:

(H$_1$):

$$F(x) = \begin{cases} f(x), & \text{if } x \in [0, a) \\ g(x), & \text{if } x \in [a, b) \\ h(x), & \text{if } x \in [b, \infty) \end{cases} \tag{2}$$

where $f \in C[[0, a], [0, \infty)]$, $g \in C[[a, b], (0, \infty)]$, and $h \in C[[b, \infty), (0, \infty)]$.

(H$_2$): functions f, g, and h are increasing on their respective domains.

(H$_3$): $f(x) < x$ for $x \in (0, a]$, $g(x) > x$ for $x \in [a, b]$, and $h(x) < x$ for $x \in [b, \infty)$

(H$_4$): $f(0) = 0$ and $\lim_{x\to\infty} h(x) = H > 0$.

(Received August 28, 2014)

1106-39-529 **Candace M. Kent*** (cmkent@vcu.edu), Virginia Commonwealth University, Dept. of Mathematics and Applied Mathematics, 1015 Floyd Avenue, Richmond, VA 23284-2014. *Piecewise-Defined Difference Equations: Open Problem.*

We consider difference equations of the form

$$x_{n+1} = f_n(x_n, x_{n-1}, \ldots, x_{n-k}), n = 0, 1, \ldots,$$

where $k \in \{0, 1, \ldots\}$, f_n is piecewise defined and $f_n : D^{k+1} \to D$, $D \subset \mathbf{R}$, whose behavior of solutions is limited to that of being either eventually periodic or unbounded. There exist numerous examples of difference equations that are both piecewise defined and characterized by having either every solution eventually periodic or every solution unbounded. We briefly describe four such cases. However, not all piecewise-defined difference equations have solutions with this behavior, and we point out some exceptions. We then present some properties that our sampling of eventually periodic or unbounded piecewise-defined difference equations have in common. We follow up with an open problem requesting an explanation as to why certain piecewise-defined difference equations have eventually periodic or unbounded solutions, and others do not. (Received September 01, 2014)

1106-39-542 **Matthew Joshua Buhr*** (matthew.buhr@coyotes.usd.edu), 2122 Highland Avenue, Albert Lea, MN 56007, Albert Lea, MN 56007. *The Flour Beetle - A Discrete Mathematical Model.* Preliminary report.

Some recent experimental studies of flour beetles (Tribolium Castaneum) have indicated a possibility of behavior in the laboratory that appears to be chaotic. I describe and attempt to analyze a model for such behavior, taking note of the properties of the life cycle of the flour beetle. The life cycle consists of larval and pupal stages, each lasting approximately two weeks, followed by an adult stage. Both larvae and adults are cannibalistic, consuming eggs and thus reducing larval recruitment. In addition, there is adult cannibalism of pupae. I will take two weeks as the unit of time and formulate a discrete mathematical model describing the larval population, pupal population, and adult population at two-week intervals. I begin with no cannibalism, then I modify my model to assume that cannibalistic acts occur randomly as the organisms move through the container of flour that forms their environment. Finding the equilibria of this basic model, I can find solutions corresponding to the extinction and also a solution corresponding to survival for some sets of additional parameter values. I can then manipulate parameter values to find if the dynamics are very sensitive to any changes in the cannibalism rate, and then determine any possible chaotic behavior. (Received September 02, 2014)

1106-39-605 **Eddy A Kwessi*** (ekwessi@trinity.edu), 1 Trinity Place, San Antonio, TX 78212, **Laila Assas**, Makkah, 10265, Saudi Arabia, **Brian Dennis** (brian@uidaho.edu), 875 Perimeter Drive MS, Moscow, ID 83844, **Saber Elaydi** (selaydi@trinity.edu), 1 Trinity Place, San Antonio, TX 78212, and **George Livadiotis** (george.livadiotis@swri.org), San Antonio, TX 78238. *Stochasticity on a modified Beverton-Holt model with Allee effects.* Preliminary report.

In this paper, we consider a Modified Discrete Beverton-Holt single species model with Allee effect. We study the effects of demographic and environmental fluctuations on the dynamic of the model, including the potential function, the attainment time, mean first passage time, stationary and exit distributions. (Received September 03, 2014)

1106-39-653 **William T Jamieson*** (bill@math.uri.edu), 5 Lippitt Road, Department of Mathematics, Kingston, RI 02881, and **Orlando Merino** (merino@math.uri.edu), 5 Lippitt Road, Department of Mathematics, Kingston, RI 02881. *Classification of the Local Dynamics of Real Analytic Planar Maps with a Non-Isolated 1-1 Resonant Fixed Point.*

We establish a complete classification of the local qualitative behavior of solutions to real analytic autonomous planar difference equations in a neighborhood of a non-isolated 1-1 resonant fixed point. Examples will be presented. (Received September 04, 2014)

1106-39-807 **Ying Zhou*** (zhou.494@mbi.ohio-state.edu) and **Bill Fagan**. *A spatial model for populations with expanding and contracting habitats.* Preliminary report.

In this talk, I will present an integrodifference equation model for the spatiotemporal dynamics of a population living in habitats with time-dependent sizes. I will show the conditions required for the resulting integral operator to be completely continuous. Bifurcation results, as well as existence and uniqueness of solutions, will then follow. (Received September 07, 2014)

1106-39-1015 **Ross Chiquet*** (rchiquet@louisiana.edu). *Chaos in a Two-stage Discrete Model with Periodic Birthrates.*

We develop a discrete juvenile-adult population model with Ricker-type survivorship functions and periodic birthrates. We first show that the extinction equilibrium, or trivial equilibrium, is locally asymptotically stable when the inherent net reproductive number is less than one. When it is greater than one, we show that the system is persistent. Given the inherent complexity of the system, several numerical examples are used to convey the rich chaotic behavior exhibited. Using bifurcation analysis, the effect of the birth rate on the system's dynamics is explored. It is shown that for certain birth rates the system exhibits chaotic behavior. We then make a comparison of the model with continuous birthrates verses one with periodic birthrates to explore the affects of different birthing strategies on the population. (Received September 09, 2014)

1106-39-1068 **Y Kostrov*** (ykostrov@xula.edu) and **Z Kudlak**. *On Systems of Rational Difference Equations with Periodic Coefficients.* Preliminary report.

In this preliminary report, we investigate the global stability, periodic character, and the boundedness nature of the solutions of several special cases which are contained in the system of difference equations

$$x_{n+1} = \frac{\alpha_n^{(1)}}{B_n^{(1)} x_n + y_n}, \quad y_{n+1} = \frac{\alpha_n^{(2)} + \beta_n^{(2)} x_n + \gamma_n^{(2)} y_n}{A_n^{(2)} + B_n^{(2)} x_n + C_n^{(2)} y_n}, \quad n \geq 0,$$

where initial conditions x_0 are y_0 are nonnegative and not both zero, and where the coefficients are nonnegative and periodic such that the denominators are always positive. (Received September 10, 2014)

1106-39-1401 **Emmanouil Drymonis*** (edrymoni@providence.edu), Department of Mathematics and Computer Sc., Providence College, Providence, RI 02918. *Some Facts and Some Open Problems and Conjectures on Rational Systems.* Preliminary report.

This talk is about the dynamics of rational systems of difference equations. We present some facts and some open problems and conjectures on rational systems. We are primarily interested in the boundedness nature of solutions, the periodic character of the equation, the global stability behavior of the equilibrium points, in invariants, and in convergence to periodic solutions including periodic trichotomies. We believe that the rational systems that we study are genuine examples which provide prototypes for the development of the basic theory of nonlinear difference equations. (Received September 12, 2014)

1106-39-1533 **George Livadiotis*** (glivadiotis@swri.edu), 6220 Culebra Rd., Div.15, San Antonio, TX 78238, and **Leila Assas**, **Brian Dennis**, **Saber Elaydi** and **Eddy Kwessi**. *Host-Parasitoid Discrete Models with strong Allee Effect.*

We introduce a discrete-time host-parasitoid model with the strong Allee effect on the host. We adapt Elaydi-Sacker model for the Allee effect on the host and Nicholson-Bailey model for the parasitism. Our model includes positive density factors due to the Allee effect, negative density factors due to intraspecific competition, and factors due to parasitism using the Poisson distribution. It is shown that there are two scenarios, the first where we have no interior fixed points and the second where we have one interior fixed point. In the first scenario, either both host and parasitoid will go to extinction or there are two regions, an extinction region where both species go to extinction and an exclusion region in which the host survives and tends to its carrying capacity. In the second scenario, either both host and parasitoid will go to extinction or there are two regions, an extinction region where both species go to extinction and a coexistence region where both species survive. More complicated dynamics with two interior fixed points characterize a generalized model, where the probability of parasitism is described by a kappa distribution. Recent developments on kappa distributions and their statistical framework are essential for interpreting the new scenarios. (Received September 13, 2014)

1106-39-1805 **Christopher S. Goodrich*** (cgood@prep.creighton.edu), 7400 Western Ave., Omaha, NE 68114. *Concavity and Convexity in Discrete Fractional Calculus.*

In this talk we will present some recent results on concavity and convexity of functions in the discrete fractional calculus. In particular, we shall indicate how certain sign conditions imposed on the operator Δ_a^ν (analogous to what one learns in the elementary single variable calculus) imply either the concavity or convexity of a function $y : \mathbb{N}_a \to \mathbb{R}$ on a subset of the function's domain. Some consideration of related open problems in the area will also be addressed. (Received September 15, 2014)

1106-39-2145 **Julia St. Goar*** (s-jstgoar1@math.unl.edu). *A Boundary Value Problem in Nabla Fractional Calculus.*

At the outset, we will review the area of discrete nabla fractional calculus. Then we will be concerned with proving the existence and uniqueness of solutions of the so-called focal boundary value problem for a difference equation involving the Caputo fractional difference. (Received September 15, 2014)

1106-39-2199 **Laila Assas*** (aslaila201@yahoo.com), Jeddah, Saudi Arabia, **Saber Elaydi** (selaydi@trinity.edu), San Antonio, TX 78212, and **Eddy Kwessi** and **George Livadiotis**, San Antonio, TX , and **Brian Dennis**, Moscow, ID. *Multispecies hierarchical competition models with the Allee effect.* Preliminary report.

In this talk we investigate the global dynamics of a multispecies hierarchical competition model with the Allee effect. We assume that each species possesses a strong Allee effect. Our focus will be on a model of three-species where the first species dominates the other two species, the second species dominates the third species, and the third species is dominated by the first two. The global dynamics of the model is determined. In particular, we show that every orbit in the positive orthant must converge to a fixed point. Finally, we show the various scenarios of the phase space portraits in which the extinction, the exclusion, and the coexistence regions are described. (Received September 16, 2014)

1106-39-2202 **Laila Assas**, Jeddah, Saudi Arabia, **Saber Elaydi*** (selaydi@trinity.edu), san antonio, TX, and **Eddy Kwessi** (ekwessi@trinity.edu) and **George Livadiotis**, San Antonio, TX , and **Brian Dennis**, Moscow, ID. *A nonautonomous hierarchical model with the strong Allee effect.* Preliminary report.

In this talk we introduce a periodic difference equation to model a hierarchical system of multispecies with the strong Allee effect and periodically fluctuating habitat. We develop the mathematical foundation of nonautonomous triangular maps which will be applied to our competition model. (Received September 16, 2014)

1106-39-2800 **Harold M Hastings*** (hastingsmail@earthlink.net) and **Michael Radin**. *Stability of difference equation formulations of Gordon-Schaefer-Munro and analogous harvesting equations.*

"The Atlantic cod stocks off the east coast of Newfoundland collapsed in 1992, forcing the closure of the fishery" (Millennium Ecosystem Assessment (www.MAweb.org, accessed 3/25/2014). We shall analyze the stability of the difference equation formulations of Gordon-Schafer-Munro, Basener-Ross and related harvesting (bioeconomic) models, following Harrison (Amer. Natur., 1979), with a goal of understanding how to forecast survival or collapse in a given parameter regime. (Received September 16, 2014)

1106-39-2912 **Sebahat Ebru Das*** (ebrudas@gmail.com), Yildiz Technical University, Department of Mathematics, Faculty of art & Sciences, Istanbul, Turkey, and **Fatma Celiker** (fatozmat@gmail.com), Yildiz Technical University, Department of Mathematics, Faculty of art & Sciences, Istanbul, Turkey. *Dynamics of a Nonlinear Rational Difference Equation.*

In this work, we investigate the global asymptotic stability of the a nonlinear rational difference equation. (Received September 17, 2014)

41 ► Approximations and expansions

1106-41-55 **George Anastassiou** and **Merve Kester***, University of Memphis, Department of Mathematical Sciences, Memphis, TN 38152. *Quantitative Approximation by Fractional Generalized Discrete Singular Operators.* Preliminary report.

In this article, we study the fractional generalized smooth discrete singular operators on the real line, the univariate and non-univariate cases, regarding their convergence to the unit operator with fractional rates in the uniform norm. The related established inequalities involve the higher order moduli of smoothness of associated right and left Caputo fractional derivatives of engaged function. Furthermore we produce fractional Voronovskaya type results giving the fractional asymptotic expansion of the basic error of our approximation. We give applications and show that our operators are not in general positive. (Received June 04, 2014)

1106-41-56 **George Anastassiou*** (ganastss@memphis.edu), University of Memphis, Department of Mathematical Sciences, Memphis, TN 38152. *Complete Fractional Monotone Approximation.* Preliminary report.

Here is developed the theory of complete fractional simultaneous monotone uniform polynomial approximation with rates using mixed fractional linear differential operators. To achieve that, we establish first ordinary simultaneous polynomial approximation with respect to the highest order right and left fractional derivatives of the function under approximation using their moduli of continuity. Then we derive the complete right and left fractional simultaneous polynomial approximation with rates, as well we treat their affine combination. Based on the last and elegant analytical techniques, we derive preservation of monotonicity by mixed fractional linear differential operators. We study special cases. (Received June 04, 2014)

1106-41-57 **George Anastassiou*** (ganastss@memphis.edu), University of Memphis, Department of Mathematical Sciences, Memphis, TN 38152. *Multivariate error function based neural network approximations.* Preliminary report.

Here we present multivariate quantitative approximations of real and complex valued continuous multivariate functions on a box or R^N, $N \in N$, by the multivariate quasi-interpolation, Baskakov type and quadrature type neural network operators. We treat also the case of approximation by iterated operators of the last three types. These approximations are derived by establishing multidimensional Jackson type inequalities involving the multivariate modulus of continuity of the engaged function or its high order partial derivatives. Our multivariate operators are defined by using a multidimensional density function induced by the Gaussian error special function.

The approximations are pointwise and uniform. The related feed-forward neural network is with one hidden layer. (Received June 04, 2014)

1106-41-161 **Gordon G Johnson*** (gjohnson10@uh.edu), Department of Mathematics, University of Houston, Houston, TX 77204-3008. *The Closure in a Hilbert Space of a PreHilbert Space CHEBYSHEV Set Fails to be a CHEBYSHEV Set.* Preliminary report.

E is the real inner product space that is union of all finite-dimensional Euclidean spaces, S is a certain bounded nonconvex set in the E having the property that every point in E has a unique nearest point in S i.e., S is a Chebyshev set. H is the Hilbert space that is the completion of E. The closure $\overline{S}$ of S, in H does not have this unique nearest point property i.e., $\overline{S}$ is not a Chebyshev set. (Received August 02, 2014)

1106-41-193 **Qiulan Qi*** (qiqiulan@163.com), , Peoples Rep of China. *Modified Kantorovich operators providing a better error estimation.*

The approximation operator for every kind of the objective function is different in approximation theory. For Lebesgue functions (or signals), local averages need to be adopted in approximation generally, i.e. using Kantorovich-type polynomials to approximate from local average. But the first and second moments of this kind of Kantorovich-type operators are not zero, which makes the problems more difficult to deal with.

King-type approximation operators preserving the test functions 1 and x^2, and have better approximation properties than the classical ones. Motivated by this, we introduce a kind of modified Kantorovich operators, which preserve the test functions 1 and x^2 and have better error estimation on the interval $[\frac{\sqrt{3}}{3}, +\infty)$ than the classical and the modified Szász-Kantorovich operators discussed in Duman. (Received August 07, 2014)

1106-41-636 **Xuemei Chen***, 202 Mathematical Sciences Bldg, columbia, MO 65203, and **Alexander Powell**, Nashville, TN. *Fusion frames and randomized subspace actions.*

A randomized subspace action algorithm is investigated for fusion frame signal recovery problems. It is noted that Kaczmarz bounds provide upper bounds on the algorithm's error moments. The main question of which probability distributions on a random fusion frame lead to provably fast convergence is addressed. In particular, it is proven which distributions give minimal Kaczmarz bounds, and hence give best control on error moment upper bounds arising from Kaczmarz bounds. Uniqueness of the optimal distributions is also addressed. (Received September 03, 2014)

1106-41-1081 **Xin Li*** (xin.li@ucf.edu), 4000 Central Florida Blvd, MSB207, Orlando, FL 32816, and **Aritra Dutta**. *Weighted low-rank matrix approximation: a new algorithm based on optimization.* Preliminary report.

Weighted low-rank (WLR) matrix approximation has many important applications in data analytics. Except in very special cases, there is no closed form solution. Many numerical algorithms have been proposed, among which most are based on some form of matrix factorizations. In this talk, we will report a new algorithm that is based on convex optimization. More precisely, we treat the problem as a constrained minimization problem with weighted matrix norm and solve it by using a unconstrained formulation. Indeed, when the Frobenius norm is used, the problem of low-rank approximation is equivalent to Principal Component Analysis. Recently, in studying the (unweighted) low-rank approximation problems, Yi Ma and his collaborators proposed Robust Principal Component Analysis by considering augmented Lagrange formulation of the constrained minimization problem using other meaningful matrix norms (like the nuclear norm, ℓ_1-norm). We are applying Yi Ma's idea to solve the weighted low-rank approximation problem. Our numerical experiments show that the algorithm works effectively and efficiently in comparison to the several existing state-of-the-art algorithms. (Received September 10, 2014)

1106-41-1084 **Aritra Dutta*** (d.aritra2010@knights.ucf.edu), 4000 Central Florida Blvd, MSB, Orlando, FL 32816, and **Xin Li** (xin.li@ucf.edu). *An Extension of a Result of Golub, Hoffman and Stewart.* Preliminary report.

The classical PCA method can provide a low rank approximation for a high-dimensional data matrix. But if one wants to preserve some elements of the matrix while approximating it by a low-rank matrix, the PCA method could not be applied. Golub, Hoffman, and Stewart ("A generalization of the Eckart-Young-Mirsky matrix approximation theorem", Linear Algebra Appl., 88/89(1987), pp. 317-327) are among the first to consider the constrained approximation by low-rank matrices. In this talk, we will present an extension of the results of Golub, Hoffman and Stewart by considering a special family of weighted approximation by low-rank matrices. We will show that the solutions to our weighted approximation problem converge to the results of Golub, Hoffman and Stewart. Unlike the methods of PCA or Golub, Hoffman and Stewart, our solutions do not admit a close form in general. We have developed a numerical algorithm for the computation of the weighted approximating matrices.

In this presentation we will demonstrate some numerical results that implement our algorithm. (Received September 10, 2014)

1106-41-1102 **Laurent Demanet*** (demanet@gmail.com). *Matrix probing and some of its applications.*
Matrix probing is a method of recovering a structured matrix from its applications to a few random vectors. Probing is a useful tool to produce semi-analytical, efficient expansions of the kernel of integral operators that stem in various ways from linear nonuniform-coefficient PDE. I will first explain the setting in which probing is provably successful, then cover two applications in numerical analysis: 1) preconditioning of the so-called wave-equation hessian, and 2) representation of the exterior Dirichlet-to-Neumann map for the Helmholtz equation, which encodes an exact absorbing boundary condition. Joint work with Jiawei Chiu and Rosalie Belanger-Rioux. (Received September 10, 2014)

1106-41-1229 **Mark A Spanier***, mark.spanier@ndsu.edu. *Extremal Signatures and Best $L^1(\mu)$-Approximations.* Preliminary report.
For a given Borel measure μ on $\mathbb{R}$, let $\mathcal{A}_1(\delta,\mu)$ be the space of entire functions of exponential type at most δ in $L^1(\mathbb{R},\mu)$. A function $\psi:\mathbb{R}\to\mathbb{C}$ such that $|\psi(x)|=1$ a.e. is called an extremal signature for μ, if

$$\int_{-\infty}^{\infty}\psi(x)F(x)\,d\mu(x)=0$$

for all $F\in\mathcal{A}_1(\delta,\mu)$. Such functions are extremely important in the study of best approximations of prescribed exponential type (bandlimited functions) in $L^1(\mu)$-norm.

For a class of measures of the form $d\mu_E(x)=|E(x)|^{-2}\,dx$ where E is a Hermite-Biehler function, we determine extremal signatures for μ_E. Using these signatures and general interpolation results, we are able to construct best $L^1(\mu_E)$-approximations to large families of functions. This presentation is based on joint work with Friedrich Littmann. (Received September 11, 2014)

1106-41-1260 **Ozgur Yilmaz***, 121-1984 Mathematics Rd, Vancouver, BC V7H1K4, Canada. *Quantization of compressed sensing measurements:exponential accuracy.*
We discuss how to efficiently quantize compressive samples of sparse or compressible signals. Our focus will be sigma-delta quantization, typically used for redundant expansions, e.g., frame expansions. We recently showed that these also provide superior approximations in the compressed sensing setting by establishing a link with frame quantization. Our original result uses a two-stage reconstruction method that relies on support recovery and works only for exactly sparse signals with no noise. There are two new results that I will describe: (1) We propose a one-stage reconstruction scheme based on a convex optimization problem that yields consistent reconstruction. We show that the reconstruction error decays inverse-polynomially with respect to the "oversampling rate" λ. Furthermore, if we optimize the order of the scheme for a given λ, the error decays root-exponentially with respect to λ. (2) We propose a method for compressing the quantized samples further via a Johnson-Lindenstrauss embedding. After modifying the one-stage decoder, this yields an error that decays exponentially as a function of the bit budget. These results apply both in fine and coarse quantization settings including 1-bit quantization. Joint work with Rongrong Wang and Rayan Saab. (Received September 11, 2014)

1106-41-1310 **Willi Freeden*** (freeden@mathematik.uni-kl.de), University of Kaiserslautern, 67663 Kaiserslautern, Germany, and **M. Zuhair Nashed** (m.nashed@ucf.edu), University of Central Florida, Orlando, FL 32816. *Multidimensional Shannon Sampling.*
The famous Shannon sampling theorem gives an answer to the question how a time signal bandlimited to a subinterval of the fundamental cell of the integer lattice can be reconstructed from discrete values in the lattice points.

In this talk, we are concerned with the problem how a space signal bandlimited to a region in multi-dimensional Euclidean space allows a reconstruction from discrete values in lattice points of a general lattice.

Weighted Hardy–Landau lattice point formulas are created to formulate explicit multi-dimensional characterizations of over- and undersampling procedures, thereby specifying not only the occurrence, but also the type of aliasing. (Received September 12, 2014)

1106-41-1394 **Stephen D. Casey*** (scasey@american.edu), Math/Stat Department, American University, 4400 Massachusetts Avenue, NW, Washington, DC 20016-8050. *Sampling Sets and Sets of Uniqueness in Both Euclidean and Non-Euclidean Domains.* Preliminary report.
Sampling theory is a fundamental area of study in harmonic analysis and signal and image processing. A fundamental component of the subject is the sampling set, a discrete set on which the information of a function can be uniquely determined and stably reconstructed. Thus, a sampling set is a set of uniqueness, a set on

which the information of the function is uniquely encoded. However, there exist sets of uniqueness that are not sampling sets. Our talk focuses on a natural way to construct these sets in both Euclidean and non-Euclidean domains. This works builds upon the author's earlier work on the inverse convolution problem, and recent work on sampling in non-Euclidean domains. (Received September 12, 2014)

1106-41-1453 **Gianluca Vinti*** (gianluca.vinti@unipg.it), Dipartimento di Matematica e Informatica, Università degli Studi di Perugia, Via Vanvitelli, 1, 06123 Perugia, Italy. *Approximation by multivariate Kantorovich sampling operators and applications to Image Processing.*

Multivariate signal analysis and inverse problems represent one of the main approaches for the image reconstruction and processing. In this talk, we present some approximation results by means of multivariate Kantorovich sampling operators and we discuss some of their applications to Image Processing. In particular, we show applications to biomedical images and to thermographic images for earthquake engineering. First, we discuss the theoretical results involving bounded continuous and uniformly continuous functions, together with a modular approximation theorem for functions belonging to Orlicz spaces. Then, an algorithm for image reconstruction based on Kantorovich sampling operators is described together with several examples and applications. (Received September 13, 2014)

1106-41-1640 **Jeff Ledford*** (jpledford@vcu.edu), 1015 Floyd Avenue, P.O. Box 842014, Richmond, VA 23284. *Recovering bivariate Paley-Wiener functions with scattered translates of the Poisson kernel.*

We introduce the Poisson interpolation operator and present various properties of this operator. The main result concerns functions whose Fourier transforms are concentrated near the origin, specifically functions belonging to the Paley-Wiener space PW_{B_β}. We show that one may recover these functions from their samples on a complete interpolating sequence for $[-\delta,\delta]^2$ by using the Poisson interpolation operator, provided that $0<\beta<(3-\sqrt{8})\delta$. (Received September 14, 2014)

1106-41-1956 **Benjamin Aaron Bailey*** (benjamin.bailey@uconn.edu), Department of Mathematics, 196 Auditorium Road U-3009, Storrs, CT 06269, and **W. R. Madych** (wolodymyr.madych@uconn.edu), Department of Mathematics, 196 Auditorium Road U-3009, Storrs, CT 06269. *Representation by the Cardinal Sine Series.*

Many aspects of the cardinal sine series, particularly those associated with the mathematical theory of sampling in signal processing, are very well known due to its role in the classical sampling theorems. The objective of this talk is to highlight several extensions of these classical theorems and to provide corresponding examples. We present (i) necessary and sufficient conditions for convergence of the series, (ii) general convergence properties and growth rates of the series, and (iii) several new classes of entire functions that can be represented via such series. Some of these classes contain members that may be unbounded on the real axis. (Received September 15, 2014)

1106-41-2170 **Rayan Saab*** (rsaab@ucsd.edu), **Rongrong Wang** and **Ozgur Yilmaz**. *Random encoding of quantized compressed sensing measurements.*

Frames generalize the notion of bases and provide a useful tool for modeling the measurement (or sampling) process in several modern signal processing applications. In the digital era, such a measurement process is typically followed by quantization, or digitization. This latter step is often followed by an encoding, or compression, stage.

Recently, compressing the bit-stream generated by Sigma-Delta quantization of random frame coefficients has been considered. It was proven that an encoding step, consisting primarily of a discrete Johnson-Lindenstrauss embedding of the quantized coefficients, yields near-optimal approximation accuracy as a function of the number of bits used.

In this talk, we show that if the same encoding scheme is applied to quantized compressed sensing measurements (with a different reconstruction scheme implemented using convex optimization), it also yields near-optimal approximation accuracy as a function of the bit-rate. (Joint work with Rongrong Wang and Ozgur Yilmaz.) (Received September 16, 2014)

1106-41-2344 **Mohammad A AlQudah*** (alqudahm@northwood.edu), 4000 Whiting Dr, Department of Mathematics, Midland, MI 48640, and **James R Angelos**. *Characterization of Best Approximation in Generalized Chebyshev Spaces.*

Let X be a finite set with the discrete topology and $C(X,\mathbb{R}^k)$ be the space of vector valued continuous functions from X to $k-$dimensional Euclidean space $\mathbb{R}^k$; and let G denote the space

$$G := Span\{u^{j,d}|u^{j,d}(x) = u_{j,d}(x)e_d, j = 1,\ldots,n_d, d = 1,\ldots,k\} \subseteq C(X,\mathbb{R}^k)$$

with $u_{j,d} \in C(X, \mathbb{R}), e_d$, the standard basis vectors in $\mathbb{R}^k$, and let $n_1, \ldots, n_k$ be the dimensions of the component spaces comprising G, with $n_1 + \ldots + n_k = n$.

This work is devoted to the study of best approximation of $f \in C(X, \mathbb{R}^k)$ from G in the uniform norm. In addition, we investigate the properties that characterize the best approximation. (Received September 16, 2014)

1106-41-2813 **Velinda R. Calvert*** (vc1@msstate.edu), **Somayeh Mashayekhi** and **Moshen Razzaghi**. *Solution of Lane-Emden type equations using Rational Bernoulli functions.*

In this talk, a numerical method for solving Lane-Emden type equations is presented. The method is based upon using rational Bernoulli functions to approximate the solution. The properties of the rational Bernoulli functions are presented. Some examples are given to demonstrate the efficiency and accuracy of the proposed method. (Received September 16, 2014)

1106-41-2943 **Ming-Jun Lai*** (mjlai@math.uga.edu), Department of Mathematics, University of Georgia, Athens, GA 30602. *A Bivariate Spline Method for Image Analysis.*

We first describe how to use bivariate box splines to construct a wavelet frame which can decompose images sharply. Comparison with other edge detection methods shows that our method is much more effectively. A few possible application of this method for object identification, letter reading, and satellite image analysis will be outlined. Finally, this method can help find a better triangulation of the image which is essential to be able to approximate image accurately. (Received September 17, 2014)

42 ► Fourier analysis

1106-42-119 **Matthew Fickus*** (matthew.fickus@afit.edu), Department of Mathematics and Statistics, Air Force Institute of Technology, Wright-Patterson AFB, OH 45433. *Some new results regarding equiangular tight frames.*

An equiangular tight frame (ETF) is a sequence of unit vectors in Euclidean space such that (i) the absolute value of any two of these vectors is some fixed constant and (ii) their corresponding rank-one orthogonal projection operators sum to a scalar multiple of the identity. In the real-variable setting, ETFs yield optimal packings of lines, that is, sets of lines whose minimum pairwise angle is as large as possible. More generally, ETFs are sequences of unit norm vectors with minimal coherence, a property that makes them valuable in communications and compressed sensing applications. Only a few general constructions of ETFs are known, and all of these rely on topics of combinatorial design such as strongly regular graphs, difference sets, balanced incomplete block designs and conference matrices. We present a few new results concerning ETFs, including some new necessary conditions on the existence of certain classes of ETFs, as well as some new approaches for constructing them. (Received July 21, 2014)

1106-42-631 **Keaton Hamm*** (khamm@math.tamu.edu). *Approximation Rates in Scattered-data Interpolation.*

We aim to discuss some of the techniques required for sampling bandlimited functions at scattered data sites. We will also discuss how certain types of approximation rates can be found in this setting. The techniques involved actually allow approximation rates for recovery of certain Sobolev functions in addition to bandlimited ones. Our main concrete example will be of forming an interpolating function by shifts of the Gaussian kernel. (Received September 03, 2014)

1106-42-980 **Bernhard G Bodmann***, 651 Phillip G Hoffman Hall, Mathematics Department, University of Houston, Houston, TX 77204, and **Nathaniel Hammen**. *Stability of phase retrieval with low-redundancy frames.*

This work concerns the recovery of vectors from magnitudes of frame coefficients when the frames have a low redundancy, meaning a small number of frame vectors compared to the dimension of the Hilbert space. In a previous paper, $4d - 4$ suitably chosen frame vectors were shown to be sufficient to uniquely determine each complex vector in d dimensions, up to an overall unimodular constant, from the magnitudes of its frame coefficients. Here, we show that semidefinite programming allows perfect reconstruction if the number of frame vectors is $6d - 3$. In this case, we derive explicit error bounds for approximate recovery when the measured magnitudes are corrupted by noise. In contrast to stability results in the previous paper, these estimates are uniform over the set of all unit-norm input vectors. (Received September 09, 2014)

1106-42-1148 **Azita Mayeli*** (amayeli@gc.cuny.edu), The Graduate Center, Mathematics Department, 365 Fifth Avenue, New York, NY 10016. *A correspondence between Paley-Wiener spaces and exponential bases.* Preliminary report.

We shall investigate the connection between translation bases for Paley-Wiener spaces and exponential Fourier bases for a domain. We apply these results to the problem of characterization of vector-valued time-frequency translates of a Paley-Wiener signal. (Received September 11, 2014)

1106-42-1274 **Demetrio Labate*** (dlabate@math.uh.edu), Department of Mathematics, 651 Phillip G Hoffman, Houston, TX 77204-3008. *Sparse shearlet representations and applications to fluorescent image analysis of neuronal cultures.*

During the last decade, a new generation of advanced multiscale representations has emerged - most notably the shearlet representation - combining the power of multiresolution analysis with high directional sensitivity and selectivity. One of the most remarkable properties of this approach is the ability to provide a precise geometric characterization of the set of singularities of multidimensional functions and distributions, going far beyond the capabilities of conventional multiscale methods. These properties provide the theoretical underpinning for several innovative algorithms for edge detection, geometric separation and feature extraction. In this talk, we will show the application of these ideas to some challenging problems from biomedical imaging aimed at the automated extraction of morphological features from fluorescent images of neuronal cultures. (Received September 11, 2014)

1106-42-1436 **Carlo Bardaro*** (carlo.bardaro@unipg.it), Department of Mathematics and Computer Sci., Via Vanvitelli, 1, 06123 Perugia, Italy, and **Paul Leo Butzer** and **Ilaria Mantellini**. *Sampling and reproducing kernel theory in the setting of Mellin transform analysis; applications.*

This invited lecture will deal with the exponential sampling theorem for Mellin bandlimited functions and its links with reproducing kernel theory and the Parseval formula in the Mellin transform setting. It will be shown that the three basic results are all equivalent to another. The sampling theorem for non-band-limited functions, which is important in engineering circles, will also be considered. Applications with detailed error analyses will be presented. (Received September 13, 2014)

1106-42-1664 **Yang Wang*** (yangwang@ust.hk), Department of Mathematics, Hong Kong Univ. of Science and Technology, Kowloon, Hong Kong. *Erasure Robust Frames.*

An important problem in the study of frames is the robustness of a frame against erasure. There is a wealth of literature on this problem. One interesting question is: in the worst case how many elements in a frame can one remove while still maintains robustness? It has been conjectured that to maintain worst case robustness one cannot remove more than 50 percent of the frame elements. In this talk, I will show that erasure robustness can be attained with erasures of arbitrary proportion. (Received September 14, 2014)

1106-42-1716 **Darrin Speegle*** (speegled@slu.edu). *Linear Independence of Time-Frequency Shifts of Functions with Decay.* Preliminary report.

The Heil-Ramanathan-Topiwala (HRT) Conjecture states that time-frequency shifts of L^2 functions are linearly independent; that is, if $0 \neq f \in L^2$ and

$$\sum c_{jk} e^{2\pi i a_k x} f(x - b_k) = 0,$$

then $c_{jk} = 0$ for all j, k.

In this talk, we describe decay conditions on f that guarantee the linear independence of time-frequency shifts, both in the general case as well as the special case when the time-frequency shifts are along a lattice. The talk surveys work that is joint with Radu Balan, Marcin Bownik, Chris Heil and Kasso Okoudjou. (Received September 15, 2014)

1106-42-1781 **Li-An Daniel Wang*** (daniel.wang@trincoll.edu), 300 Summit Street, Hartford, CT 06114. *Extrapolation theory in variable Lebesgue Spaces.*

Variable Lebesgue spaces $L^{p(\cdot)}$ are natural generalizations of the classical L^p space, where the variable exponent $p(\cdot)$ is allowed to vary. We will introduce these spaces, and look at recent results that use weighted extrapolation theory of Rubio de Francia. (Received September 15, 2014)

1106-42-1820 **Ghanshyam Bhatt*** (gbhatt@tnstate.edu), Nashville, TN 37209. *Bases, frames and associated operators from graphs and vertices.*

Bases are sometimes inadequate for some desired applications like signal processing. Frames are linearly dependent spanning sets, so they are generalization of basis. The graphs with n vertices can provide some nice frames in R^n. In this talk we will discuss some of the properties of frames and their connections with the vertices of a graph. (Received September 15, 2014)

1106-42-2007 **David Montague*** (davmont@stanford.edu) and **Bala Rajaratnam** (brajarat@stanford.edu). *Positive definite sequences and positivity with applications to spatial random fields.*

We look at functions retaining positivity of special classes of covariance matrices associated with spatial random fields. In particular, we consider sufficient conditions for retaining positivity when applying element-wise thresholding to such classes of positive definite functions. (Received September 15, 2014)

1106-42-2126 **Alexander M Powell***, Vanderbilt University, Department of Mathematics, Nashville, TN 37240, and **Tyler Whitehouse**. *Error bounds for consistent reconstruction.*

Consistent reconstruction is a technique for reconstructing a signal from a set of quantized linear measurements. We prove mean squared error bounds (MSE) for consistent reconstruction in the setting of random frames and under the uniform quantization noise model. In particular, we prove that the mean squared error for consistent reconstruction is of the order C/N^2 where N is the frame size, and we prove bounds on the associated dimension dependent constant C. Our results require an analysis of random polytopes generated by affine hyperplanes and of associated coverage processes on the sphere. This is joint work with Tyler Whitehouse. (Received September 15, 2014)

1106-42-2228 **Rim Gouia-Zarrad*** (rgouia@aus.edu), Department of Mathematics and Statistics, American University of Sharjah, United Arab Emirates. *Reconstructing a function from its conical Radon transform.*

In recent years, Radon type transforms that integrate functions along families of curves or surfaces, have been intensively studied due to their applications to inverse scattering, synthetic aperture radar, imaging science, nuclear industry, etc. In this presentation, we consider the transform that integrates a function f over a family of cones invariant to translation. A new exact inversion formula is presented in the case of fixed opening angle and vertical central axis. In addition, the results of numerical simulations are presented to demonstrate the efficiency of the suggested algorithm in 2D. (Received September 16, 2014)

1106-42-2259 **Dustin G. Mixon*** (dustin.mixon@gmail.com). *Compressive classification and the rare eclipse problem.*

This talk addresses the fundamental question of when convex sets remain disjoint after random projection. I will discuss recent results based on ideas from high-dimensional convex geometry. These results show that data can be acquired for classification via very few measurements without requiring sparsity.

(Joint work with Afonso S. Bandeira and Benjamin Recht.) (Received September 16, 2014)

1106-42-2702 **Matthew Ferrara**, **Jason T. Parker** and **Margaret Cheney*** (cheney@math.colostate.edu). *Resolution Optimization with Irregularly Sampled Fourier Data.*

Image acquisition systems such as synthetic-aperture radar and magnetic resonance imaging often measure irregularly spaced Fourier samples of the desired image. In this work we show the relationship between sample locations, their associated backprojection weights, and image resolution as characterized by the resulting point-spread function. Two new methods for computing data weights, based on different optimization criteria, are proposed. (Received September 16, 2014)

1106-42-2940 **Marcin Bownik***, Department of Mathematics, University of Oregon, Eugene, OR 97403, and **Karol Dziedziul**. *Smooth orthogonal projections on sphere.*

We construct a decomposition of the identity operator on the sphere $\mathbb{S}^d$ as a sum of smooth orthogonal projections subordinate to an open cover of $\mathbb{S}^d$. We give applications of our main result in the study of function spaces and Parseval frames on the sphere. (Received September 17, 2014)

43 ► Abstract harmonic analysis

1106-43-244 **Vignon S Oussa*** (voussa@bridgew.edu), Bridgewater, MA. *Sampling and Interpolation on some Nilpotent Lie Groups.*

Using well-known results of frame theory and time-frequency analysis, we establish the existence of sampling subspaces of square integrable functions over some non-commutative nilpotent Lie groups. We will also present recent surprising results on the existence of sampling spaces over non commutative nilpotent Lie groups which enjoy the interpolation property. (Received August 14, 2014)

1106-43-485 **Clare G Wickman*** (clare.wickman@jhuapl.edu). *Probabilistic Frames: Ideas from Optimal Transport.* Preliminary report.

Abstract: Probabilistic frames are subset of the Wasserstein space of probability measures with finite second moment, and they provide one generalization of finite frames. The Wasserstein space is a metric space of probability measures, endowed with a metric whose definition comes from Monge-Kantorovich optimal transport problem. By examining frames within the optimal transport framework, previously difficult analysis can be performed, such as comparing frames with different cardinalities. Within the context of the Wasserstein space, familiar concepts in frames such as analysis, synthesis, and duality can be reformulated. Analogies can be drawn to fusion frames, and frame geodesics can be constructed in the Wasserstein space. Other problems in frame theory can also be reposed in this space. (Received August 30, 2014)

1106-43-595 **Karin Schnass*** (kschnass@uniss.it), Porto Conte Ricerche, 07041 Alghero, Italy. *A tour from sparse approximation over dictionary learning to random sparse properties of frames.* Preliminary report.

Overcomplete frames are a popular choice when trying to sparsely - compactly represent a class of signals. In this talk we will start with a short introduction into dictionary learning where one tries to find the frame which allows for the sparsest representation of a given signal class. Motivated by the theoretical analysis of K-SVD, a widely applied dictionary learning algorithm, we will then present an interesting problem concerning the expected image of the projection onto a subspace spanned by randomly chosen S frame/dictionary elements. We show the experimental behaviour of the operator in question for several underlying frames and then present some very preliminary theoretical results for special choices of the sparsity level S and the underlying frame. (Received September 03, 2014)

1106-43-1605 **Maxim J Goldberg** (mgoldber@ramapo.edu), TAS, Ramapo College of NJ, Mahwah, NJ 07430, and **Seonja Kim*** (seonja777@hotmail.com), Department of Mathematical Sciences, University of Cincinnati, Cincinnati, OH 45221. *Does Lipschitz imply fast convergence of a diffusion-smeared function to itself as time goes to 0?* Preliminary report.

For a diffusion semigroup A_t on some function space, it is natural to investigate the relationship between smoothness of a function f and the speed of convergence of $A_t f$ to f as $t \to 0^+$. Recently, R.R. Coifman and W.E. Leeb have proposed a family of multi-scale diffusion metrics on the underlying measure space. To show that Lipschitz implies fast convergence of $A_t f$ to f, they assume a certain rate of decay, as $t \to 0^+$, of the expected value of the distance from a generic point x to another point in the underlying measure space, with respect to the probability density associated with the diffusion at time t. It would be useful to know more about when this assumption holds.

In our work, we show that we can replace the L_1 metric of probability densities at time t used by Coifman and Leeb to construct their diffusion distance family, by an appropriate, automatically normalized L_2 metric using *square roots* of the probability densities. This metric, or rather its square, leads to more explicit computation of an integral which is relevant to establishing the extra assumption above. Moreover, power decay of this integral with respect to our metric is equivalent to power decay using the original L_1 metric. (Received September 16, 2014)

44 ► *Integral transforms, operational calculus*

1106-44-1941 **Lance Nielsen*** (lnielsen@creighton.edu), Department of Mathematics, Creighton University, Omaha, NE 68178. *Towards a Comprehensive Stability Theory for Feynman's Operational Calculus: The Time Independent and Time-Dependent Settings.* Preliminary report.

Via a general construction, we are able to establish a quite general and comprehensive stability theory for Feynman's operational calculus (forming functions of noncommuting operators) in the time independent setting. In particular, we are able to establish stability of the operational calculus with respect to general types of the time-ordering measures. While the domain of the operational calculus is somewhat restricted as compared to the "standard" version of the operational calculus (established by Jefferies and Johnson), the advantages of this relatively minor domain restriction are significant in that the stability theory (with respect to the time-ordering measures) as it stands at this time is contained, essentially in its entirety, in the principle result of the time independent setting.

The same construction used in the time independent setting leads to essentially the same result for the "standard" version of the operational calculus (with the same slight restriction of the domain) in the time-dependent setting, with only a mild change in order to accommodate the presence of time-dependent operators; i.e., operator-valued functions. As above, much of the existing stability theory for the time-dependent setting is contained in the principle result. (Received September 15, 2014)

46 ► Functional analysis

1106-46-36 **Talat Nazir*** (dr.talatnazir@gmail.com), Department of Mathematics and Computer, Technical University Eindhoven, 5612 AZ, The Netherlands, 5612 Eindhoven, Brabant, Netherlands. *Some Approximate Fixed Point Results for Generalized Nonexpansive Mappings in Ptolemy Spaces.* Preliminary report.

In this paper, using the setting of Ptolemy's inequality in a metric space, we obtain some new approximate fixed point results. Some examples are given to validate the concepts and results presented herein. The well-posedness of the approximate fixed point problem is also studied. The proved results unify and improve many recent results of existing literature. (Received May 11, 2014)

1106-46-79 **Hudson Akewe*** (hakewe@unilag.edu.ng), Department of Mathematics, University of Lagos, Akoka, Lagos, Lagos, Nigeria 234(01), Nigeria, and **A. A. Mogbademu** (amogbademu@unilag.edu.ng), Department of Mathematics, University of Lagos, Lagos, 234(01), Nigeria. *Common Fixed Point of Jungck- Kirk-type Iterations for Non-self Operators in Normed Linear Spaces.* Preliminary report.

In this paper, we introduce Jungck-Kirk-multistep and Jungck-Kirk-multistep-SP iterative schemes and use their strong convergences to approximate the common fixed point of nonself operators in a normed linear Space. The Jungck- Kirk-Noor, Jungck-Kirk-SP, Jungck-Kirk-Ishikawa, Jungck-Kirk- Mann and Jungck-Kirk iterative schemes follow our results as corollaries. We also study and prove the stability results of these schemes in a Banach space. Our results generalize and unify most approximation and stability results in the literature
(Received July 04, 2014)

1106-46-108 **Bhavana Deshpande*** (bhavnadeshpande@yahoo.com). *Coupled coincidence point and coupled fixed point theorems on modified intuitionistic fuzzy metric spaces with applications.* Preliminary report.

In this talk, we discuss some coupled coincidence point and coupled fixed point theorems for nonlinear mixed monotone-generalized contractions on partially ordered modified intuitionistic fuzzy metric spaces. We also discuss coupled coincidence point and fixed point theorem for weakly compatible mappings on modified intuitionistic fuzzy metric spaces. We apply our results to study the existence and uniqueness of the solution to a nonlinear Fredholm integral equation. We provide examples to demonstrate our results. (Received July 17, 2014)

1106-46-204 **Nabin Kumar Sahu*** (nabin6582@gmail.com), Faculty Block-4, Room No. 4205, Dhirubhai Ambani Institute of Information and, Communication Technology, Gandhinagar, Gujarat, 382007, India. *Variational Inclusions and Algorithms in Uniformly Convex Smooth Banach Spaces.*

This presentation deals with a new system of nonlinear variational inclusion problems involving (A, η)-maximal relaxed monotone and relative (A, η)-maximal monotone mappings in 2-uniformly smooth Banach spaces. Using the generalized resolvent operator technique, the approximation solvability of the proposed problem is discussed. An iterative algorithm is constructed to approximate the solution of the problem. Convergence analysis of the proposed algorithm is investigated. Similar results are also explored for other system of variational inclusion problems involving relative (A, η)-maximal monotone mappings and (H, η)-maximal monotone mappings.
(Received August 15, 2014)

1106-46-209 **Dr. nihar kumar mahato*** (nihariitkgp@gmail.com), IIITDM Jabalpur, P.O. : Khamaria, Jabalpur, M. P. 482 005, India. *Equilibrium Problems, multi-valued, variational-like inequalities.*

In this presentation, we establish the existence and uniqueness solutions of a generalized mixed equilibrium problem (in short, (GMEP)) using the generalized relaxed η-α-monotonicity in Banach spaces. We also present

a hybrid iteration scheme by the generalized f-projection operator to find a common element of the solutions of the (GMEP) and the set of fixed points of an infinite family of quasi-ϕ-nonexpansive mappings in a uniformly smooth and uniformly convex Banach space. Moreover, the strong convergence of the newly proposed method under generalized relaxed η-α-monotonicity is considered. (Received August 11, 2014)

1106-46-298 **Jonathan Rosenberg*** (jmr@math.umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742-4015. *Structure and applications of real C^*-algebras.*

For a long time, practitioners of the art of operator algebras always worked over the complex numbers, and nobody paid much attention to real C^*-algebras. Over the last thirty years, that situation has changed, and it's become apparent that real C^*-algebras have a lot of extra structure not evident from their complexifications. At the same time, interest in real C^*-algebras has been driven by a number of compelling applications, for example in representation theory, in the classification of manifolds of positive scalar curvature, and in the study of orientifold string theories. We will discuss a number of interesting examples of these. (Received August 20, 2014)

1106-46-319 **Ioana Ghenciu*** (ioana.ghenciu@uwrf.edu). *Limited sets and bibasic sequences.*

Bibasic sequences are used to study relative weak compactness and relative norm compactness of limited sets. (Received August 21, 2014)

1106-46-323 **Marc A Rieffel*** (rieffel@math.berkeley.edu), Department of Mathematics, University of California, Berkeley, CA 94720-3840. *Matricial bridges for "matrix algebras converge to the sphere".* Preliminary report.

In earlier papers I provided a way to give meaning to physicists' statements such as "a sequence of matrix algebras of increasing dimension converge to the 2-sphere" (or to other spaces). This involved giving the matrix algebras the structure of non-commutative metric spaces, and then developing suitable types of non-commutative Gromov-Hausdorff distance (using "bridges") for which I could then prove convergence of the matrix algebras. But the types of Gromov-Hausdorff distance that I developed had flaws. Very recently Latremoliere introduced a substantially better type of Gromov-Hausdorff distance, which he calls "propinquity". I will describe a somewhat general framework that is very convenient for applying Latremoliere's theory to the matrix algebra situation. I will also describe a matricial form of this framework. A matricial form is needed for working with "vector bundles" (projective modules) over non-commutative metric spaces that are close together for Gromov-Hausdorff distance. (Received August 21, 2014)

1106-46-326 **Peter G. Casazza*** (casazzap@missouri.edu), 116 Math Sciences Building, Columbia, MO 65211, **Lindsey M. Woodland** (lmwvh4@missour.edu), 221 Math Sciences Building, Columbia, MO 65211, and **Kevin Brewster** (kjb886@mizzou.edu), 221 Math Sciences Building, Columbia, MO 65211. *Distribution of Hilbert Space Frame Coefficients.*

The most fundamental operation performed on frames is the frame expansion by the frame coefficients. Yet, little is known about the distribution of the frame coefficients of vectors in a Hilbert space. Here we make a deep and detailed study of the distributon of frame coefficients and show that in the case of equiangular tight frames we can get fairly exact representations for this. We also give the best possible distributions for all frames (and unit norm tight frames) in terms of majorization. There are many more fundamental results here. We also give examples to show that all our results are best possible. (Received August 22, 2014)

1106-46-336 **Ji Gao*** (jgao@ccp.edu), Department of Mathematics, Community College of Philadelphia, Philadelphia, PA 19130, and **Satit Saujung** (saejung@kku.ac.th), 1, Sriayudthaya Road, Bangkok, 10400. *n-Dimensional U-Convexity and Fixed Point for Non-expansive Mappings in Banach Spaces.* Preliminary report.

Definition 1: Let $x \in S_X$ and $\nabla_x \subset S_{X^*}$ be the norm 1 supporting functionals at x. Then

(1) $$m(x_1, x_2, \dots, x_{n+1}; f_1, f_2, \dots, f_n) := \begin{bmatrix} 1 & 1 & \cdots & 1 \\ \langle x_1, f_1\rangle & \langle x_2, f_1\rangle & \cdots & \langle x_{n+1}, f_1\rangle \\ \vdots & \vdots & \ddots & \vdots \\ \langle x_1, f_n\rangle & \langle x_2, f_n\rangle & \cdots & \langle x_{n+1}, f_n\rangle \end{bmatrix}$$

where $\{x_1, x_2, \dots, x_{n+1}\} \subseteq X$, $\{f_1 \in \nabla_{x_1}, f_2 \in \nabla_{x_2}, \dots, f_n \in \nabla_{x_n}\} \subseteq X^*$ and $n \in \mathbb{N}$, and

(2) $v(x_1, x_2, \dots, x_{n+1}) := \sup\{\det m(x_1, x_2, \dots, x_{n+1}; f_1, f_2, \dots, f_n) : f_1 \in \nabla_{x_1}, f_2 \in \nabla_{x_2}, \dots, f_n \in \nabla_{x_n}\}$.

We introduce the modulus of n-dimensional U-convexity as follows:

Definition 2: Let X be a Banach space. Then

$$\delta^n_{w,X}(\varepsilon) := \inf\{1 - \frac{1}{n+1}\|x_1 + x_2 + \cdots + x_{n+1}\| : x_1, x_2, \ldots x_{n+1} \in S_X, v(x_1, x_2, \ldots, x_{n+1}) \geq \varepsilon\},$$

where $0 \leq \varepsilon \leq 2^n$.

In this talk, we show the relationship between this concept and fixed point of non-expansive mappings and other geometric properties in Banach spaces. (Received August 23, 2014)

1106-46-337 **William E Gryc*** (wgryc@muhlenberg.edu) and **Todd Kemp**. *A Sharp Inequality for Taylor Coefficients in Fock Spaces.*

For $\alpha > 0$ and $1 < p < \infty$, let F^p_α denote the set of all holomorphic functions of one complex variable who have finite L^p norm against the gaussian probability measure whose Radon-Nikodym derivative against Lebesgue measure is $\frac{\alpha p}{2\pi}\exp\left(-\frac{\alpha p}{2}|z|^2\right)$. F^p_α is sometimes called a Fock space or a Segal–Bargmann space. For $f \in F^p_\alpha$, let $\|f\|_{p,\alpha}$ denote the L^p norm described above. Furthermore for any $f \in F^p_\alpha$ and nonnegative integer n, let a_n denote the n^{th} Taylor coefficient of f (centered at 0). We will prove that $|a_n| \leq \frac{\left(\frac{\alpha p}{2}\right)^n}{\Gamma\left(\frac{np}{2}+1\right)}\|f\|_{p,\alpha}$, and that this inequality is equality if and only if f is a constant multiple of z^n. (Received August 23, 2014)

1106-46-364 **Chunlan Jiang**, **Zhengwei Liu*** (zhengwei.liu@vanderbilt.edu) and **Jinsong Wu**. *Noncommutative uncertainty principles.*

The classical uncertainty principles deal with functions on abelian groups. In this paper, we discuss the uncertainty principles for finite index subfactors which include the cases for finite groups and finite dimensional Kac algebras. We prove the Hausdorff-Young inequality, Young's inequality, the Hirschman-Beckner uncertainty principle and the Donoho-Stark uncertainty principle. We characterize the minimizers of the uncertainty principles. We also prove that the minimizer is uniquely determined by the supports of itself and its Fourier transform. The proofs take the advantage of the analytic and the categorial perspectives of subfactor planar algebras. Our method to prove the uncertainty principles also works for more general cases, such as Popa's λ-lattices, modular tensor categories etc. (Received August 25, 2014)

1106-46-413 **Ronald G. Douglas*** (rgd@tamu.edu), TAMU-3368, College Station, TX 77843. *Maps similar to essentially normal ones.* Preliminary report.

Almost fifty years ago, P. Rosenthal and the author characterized operators similar to normal ones in terms of the Gelfand transform on its double commutant. This result also extends to commuting n-tuples. In this talk we discuss attempts to extend the reesult to essential normality. This circle of ideas is related to the BDF theory and homomorphisms into the Calkin algebra. (Received August 27, 2014)

1106-46-475 **Nigel Higson*** (higson@math.psu.edu), Department of Mathematics, Penn State University, University Park, PA 16802. *Operator algebras, operator spaces and categories of representations.* Preliminary report.

I shall describe some categories of tempered representations of reductive groups, and parabolic induction functors between them, that are constructed using ideas from operator algebras and operator spaces. Some of the features of these categories suggest that operator algebra techniques have a novel conceptual role to play in tempered representation theory. (Received August 29, 2014)

1106-46-544 **Mikael Rordam*** (rordam@math.ku.dk), Department of Mathematics, University of Copenhagen, Universitetsparken 5, 2100 Copenhagen, Denmark. *Elementary amenable groups are quasidiagonal.*

Rosenberg proved in 1987 that if the reduced group C^*-algebra of a group is quasidiagonal, then the group is amenable; and he conjectured that the reverse may also hold. We confirm Rosenberg's conjecture for the class of elementary amenable groups, and, in fact, a somewhat larger class. The proof uses results from the classification program of Elliott for simple nuclear C^*-algebras, in particular recent results of Matui and Sato in combination with the work of Lin, Winter and others.

This is a joint work with N. Ozawa and Y. Sato. (Received September 02, 2014)

1106-46-570 **Weihua Li*** (wli@colum.edu). *The Similarity Degree of Approximately Divisible C^*-algebras.*

Let $\mathcal{A}$ be a unital approximately divisible C*-algebra. We show that the similarity degree of $\mathcal{A}$ is at most 5. (Received September 02, 2014)

1106-46-614 **Terje Hõim***, Wilkes Honors College, Florida Atlantic Univ., Jupiter, FL 33458, and Univ. of Tartu, Tartu, Estonia, and **D. A. Robbins**, Dept. of Mathematics, Trinity College, Hartford, CT 06106. *Cover-strict topologies and algebraic structures for some spaces of vector-valued functions.* Preliminary report.

Let X be a completely regular Hausdorff space, and $\mathcal{D}$ a cover of X. Mati Abel, J. Arhippainen, and J. Kauppi in [Mediterr. J. Math. 7 (2010) 271-282] and [Cent. Eur. J. Math. 10 (2012), 1060-1066] describe the cover-strict topology on $C_b(X,\mathcal{D})$, the space of continuous scalar-valued functions on X which are bounded on each $D \in \mathcal{D}$, and investigate the ideal and quotient structures of $C_b(X,\mathcal{D})$. We use ideas from the theory of bundles of topological vector spaces (in particular, bundles of Banach spaces and Banach algebras), as found in e.g. G. Gierz [Lect. Notes Math. 955 (Springer-Verlag, 1982)] and the present authors' papers [Acta Comment. Univ. Tartuensis Math. 14 (2010), 75-90] and [Quaest. Math. 34 (2011), 361-376] to define analogous topologies on section spaces of such bundles, and to discuss completeness properties, ideals, and quotients of such spaces. (Received September 03, 2014)

1106-46-628 **Michael Anshelevich*** (manshel@math.tamu.edu), Department of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77843-3368, and **John D Williams**, Universität des Saarlandes, FR 6.1-Mathematik, 66123 Saarbrücken, Germany. *Operator-valued monotone convolution semigroups.* Preliminary report.

We consider semigroups, under composition, of transformations of the upper-half-plane over a C^*-algebra. Under mild continuity assumptions, we show that such a semigroup has an infinitesimal generator, which determines it. Under stronger assumption that the transformations are F-transforms of distributions, we obtain a detailed description of the generator. This allows us to extend the operator-valued Bercovici-Pata bijection to monotone convolution. (Received September 03, 2014)

1106-46-662 **Arnaud Brothier*** (arnaud.brothier@vanderbilt.edu). *Weak amenability for subfactors.*

Cowling and Haagerup introduced weak amenability for groups. Hence to any group one can attach a real number called the Cowling-Haagerup constant. Weak amenability plays a key role in classification of von Neumann algebras and in deformation/rigidity theory. I will define those notions for subfactors and show that the Cowling-Haagerup constant only depends on the standard invariant. I will explain how this notion is a generalization of the classical one for groups and give exotic examples of subfactors that are weakly amenable. (Received September 04, 2014)

1106-46-711 **Yunyun Esther Yang*** (yyang18@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *Distributions in Spaces with Thick Points.*

I will introduce our recent work in a theory of distributions where one special point, a thick point, is present. The theory of thick distributions was initially introduced to deal with the occurrence of a distributional singularity. We used asymptotic expansions to define a new class of test functions. I will present our construction of the thick test function space and the thick distribution space; the study of several operations on these distributions; several important examples. This is a joint work with Professor Ricardo Estrada.
(Received September 05, 2014)

1106-46-750 **Roger R. Smith*** (rsmith@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77843, and **Florin Pop** (fpop@wagner.edu), Department of Mathematics, Wagner College, Staten Island, NY 10301. *Cohomology theory for von Neumann algebras.*

Building on the earlier work of Hochschild in the algebraic setting, Dick Kadison and his collaborators Barry Johnson and John Ringrose developed the theory of continuous Hochschild cohomology for von Neumann algebras. This talk will survey the earlier results in this area, and discuss more recent results on the second cohomology groups of non-prime factors. (Received September 05, 2014)

1106-46-754 **Gulnara Abduvalieva** and **Dmitry Kaliuzhnyi-Verbovetskyi*** (dmitryk@math.drexel.edu). *Implicit/inverse function theorems for free noncommutative functions.* Preliminary report.

Free noncommutative functions are mappings of matrices to matrices which preserve matrix size and respect direct sums and similarities. We prove implicit/inverse function theorems for free noncommutative functions on the set of tensor-algebra nilpotent matrices over a module and on a domain of matrices over an operator space. (Received September 05, 2014)

1106-46-790 **Liming Ge*** (liming@unh.edu), Academy of Math and Systems Science, 55 ZhongGuanCun East Road, Beijing, 100190, Peoples Rep of China. *Topology of natural numbers and entropy of arithmetic functions.* Preliminary report.

Compactification of natural numbers is studied in association with their addition and multiplication. Gelfand-Naimark's theorem on abelian C*-algebras is applied to characterize the associated compact Hausdorff spaces. Entropy for arithmetic functions is introduced. Connections with number theory are explained. (Received September 06, 2014)

1106-46-800 **Søren Eilers*** (eilers@math.ku.dk), Department of Mathematical Sciences, University of Copenhagen, Universitetsparken 5, 2100 Copenhagen, Denmark, and **Xin Li** and **Efren Ruiz**. *Classifying right-angled Artin semigroup C^*-algebras.*

The right-angled Artin groups and semigroups are defined from undirected graphs by associating one generator to each vertex, and imposing commutativity on pairs of generators exactly when they are connected by edges. In a completely similar vein, one can study operators on Hilbert spaces which are required to commute according to data arising from the graph, and recent insight has clarified the sense in which the latter such definition is founded on the second in the semigroup case.

Employing classification theory for non-simple C^*-algebras, we have obtained a complete description of these *right-angled Artin semigroup C^*-algebras* by their K-theory, which reflects the geometry of the graph through the Euler characteristic. Among many other things, this leads to surprisingly strong results on the stability of some such operators, showing that if a familiy of operators satisfy the relevant relations up to a small error, then they can be perturbed a bit to obtain an exact match. (Received September 07, 2014)

1106-46-834 **Ken Dykema*** (kjd@tamu.edu), **Claus Koestler** and **John D. Williams**. *Symmetric states and tail algebras.* Preliminary report.

We study symmetric states on the universal free product $\mathfrak{A} = *_1^\infty A$ of a unital C^*-algebra A with itself infinitely many times. The tail algebra $\mathcal{T}_\psi$ of such a state is a naturally defined von Neumann subalgebra of the von Neumann algebra $\mathcal{M}_\psi$ generated by the image of $\mathfrak{A}$ under the GNS representation. The classical and noncommutative de Finetti theorems are concerned with independence and free independence over the tail algebra.

An example of Weihua Liu shows that there need not be a normal conditional expectation from $\mathcal{M}_\psi$ onto $\mathcal{T}_\psi$. We consider several related issues, and construct a *tail C^*-algebra* and associated conditional expectation. There are some open questions about these constructions. Specializing to the case of quantum symmetric states, these constructions allow a classification of quantum symmetric states in terms of free products with amalgamation. (Received September 07, 2014)

1106-46-849 **J William Helton*** (helton@ucsd.edu), Math Dept, UCSD, La Jolla, CA 92093. *Noncommutative Inequalities.* Preliminary report.

The talk will cover aspects of inequalities for non-commutative functions in free *-algebras done with Igor Klep, Scott McCullough. At this point we have classifications of free convex rational functions and semialgebraic sets. There are shockingly few; all are identified with Linear Matrix Inequalities (LMIs). Now we undertake to develop a theory of change of variables to achieve matrix convexity. Our approach uses free *-algebra versions of the classical real algebraic geometry Positivstellensatze and Nullstellensatze which have been developing over the last few years.

The work originates in trying to develop a theory suited to the matrix inequalities which are ubiquitous in linear engineering systems and control. The talk will be co-ordinated with Scott McCullough's talk, though his will focus on a bridge between traditional commutative LMIs and LMIs with matrix variables, a subject motivated by pursuits in the optimization community. (Received September 08, 2014)

1106-46-851 **Erling Størmer*** (erlings@math.uio.no), Department of Mathematics, University of Oslo, 0316 Oslo, Norway, Oslo, Norway. *Separable states and positive maps.*

The subject of positive linear maps between C*-algebras started with Dick's famous papers on isometries and the generalized Schwarz inequality in the early 1950s. Personally I had the luck of having Dick as my thesis advisor for my dr. thesis on positive maps. The theory developed rather slowly until it became clear in the 1990s that positive maps are important in the study of entanglement in quantum information theory. An important class of states on tensor products of matrix algebras are the separable ones, which are sums of product states. It is a very difficult problem to find sufficient conditions for states to be separable. In my talk I'll give a necessary condition for states to be separable and then apply this to give a negative answer to a conjecture on separability of the so-called SPA of a positive map. (Received September 08, 2014)

1106-46-903 **David Penneys***, 520 Portola Plaza, Math Sciences Building 6363, UCLA Mathematics Department, Los Angeles, CA 90095-1555. *Classifying small index subfactors.*

We classify subfactors by three invariants of increasing complexity: the index, the principal graph, and the standard invariant. The standard invariant is a unitary 2-category which generalizes the representation category of a (quantum) group, and thus we think of subfactors as objects which encode quantum symmetries. In one sense, subfactors of small index are the simplest examples of subfactors, and we have a complete classification of their standard invariants to index 5. I will discuss the ongoing subfactor classification program and the search for exotic examples. (Received September 08, 2014)

1106-46-910 **Mishko Mitkovski*** (mmitkov@clemson.edu), Department of Mathematical Sciences, Martin Hall, Clemson, SC 29634. *Function theory in Hilbert spaces with generalized frames.* Preliminary report.

A well known method for studying the properties of Hilbert space operator(s) is by representing it(them) as simple operator(s) acting on an appropriate classical function space. In this setting we often exploit the holomorphic structure that this function space usually posses. For this reason many of the basic operator theoretic results were developed for specific classes of operators acting on a variety of specific function spaces. In this talk, we will show that many of these fundamental notions and results, can be also developed in the context of general Hilbert spaces that posses a generalized frame (indexed by a locally compact group). These include but are not limited to: Carleson measures, sampling and interpolation, Hankel and Toeplitz operators, dilation results, etc. In the classical theory the generalized frame is often given by the family of all/some reproducing kernels, but we will present how similar result can be also obtained even for spaces that don't have any reproducing kernels. (Received September 08, 2014)

1106-46-921 **Zhe Liu*** (zhe.liu@ucf.edu). *Recent developments in the theory of Murray-von Neumann algebras.*

Our discussion begins with a survey of the theory of algebras of operators affiliated with finite von Neumann algebras (Murray-von Neumann algebras). A discussion of recent results (involving commutators) follows this survey. (Received September 08, 2014)

1106-46-964 **Richard Kadison*** (kadison@math.upenn.edu). *Extensions of Pure States. Murray-von Neumann Algebras.*

The lecture will consist of two parts. In the first part, we discuss the problems involving uniqueness of extensions of pure states and the possible physical implications of what I. M. Singer and the speaker proved in their 1959 article and the recent proposed solution to the problem posed in that article. In the second part of the lecture, we discuss, as time allows, further developments involving commutators and derivations in Murray-von Neumann algebras (based on the material presented in the lecture of Zhe Liu). (Received September 09, 2014)

1106-46-1024 **Magnus B Landstad*** (magnusla@math.ntnu.no). *Proper actions and coactions.* Preliminary report.

If a locally compact group G acts on a locally compact space X, the action is called *proper* if the map $(g, x) \mapsto (gx, x)$ is proper. This is the usual definition, but there is also a weaker notion (usually called *wandering*) which only requires that the map $g \mapsto gx$ is proper for all x.

I shall discuss various extensions of these concepts to actions and coactions of groups on C^*-algebras.

This is joint work with Steve Kaliszewski and John Quigg. (Received September 09, 2014)

1106-46-1072 **Sorin Popa*** (popa@math.ucla.edu), Department of Mathematics, UCLA, Los Angeles, CA 90095. *Towards a good cohomology theory for II_1 factors.* Preliminary report.

Abstract. I will comment on the recent efforts to find a "good" 1cohomology theory for II_1 factors M, i.e. one that does not always vanish and that can detect properties of II_1 factors such as primeness, absence of Cartan subalgebras, infinite generation, etc. Ideally, such a theory should be calculable and in the case of group II_1 factors $M = L(\Gamma)$ it should reflect the cohomology theory of the group Γ. (Received September 10, 2014)

1106-46-1143 **Judith A. Packer***, Campus Box 395, Department of Mathematics, University of Colorado, Boulder, Boulder, CO 80309. *Projective multiresolution structures for direct limits of C^*-algebras.* Preliminary report.

Let $\{C_j\}_{j=0}^{\infty}$ be a nested sequence of unital C^*-algebras with the direct limit C^*-algebra $\mathcal{C}$ preserving the unit, and let $\mathcal{X}$ be a finitely generated (left) projective $\mathcal{C}$-module. We define the notion of a *projective multiresolution structure* for the pair $(\mathcal{C}, \mathcal{X})$. We give examples from the theory of noncommutative solenoids that indicate that projective multiresolution structures are the correct objects for studying equivalence bimodules between direct limit algebras. This work is joint with F. Latrémolière of the University of Denver. (Received September 11, 2014)

1106-46-1218 **Hueytzen J. Wu*** (kfhjw00@tamuk.edu), Department of Mathematics, MSC 172, Texas A & M University - Kingasville, Kingsville, TX 78363, and **Wan-Hong Wu**. *Generalized Stone-Weierstrass Theorem for C*(Y).*

Let C*(Y) be the set of all bounded real continuous functions on a topological space Y with the supremum norm. Let R be the equivalence relation on the set S of all C*(Y)-nets defined by [xi] R [xj] iff lim[f(xi)] is equal to lim[f(xj)] for all f in C*(Y). Let [xi]* be the equivalence class containing the C*(Y)-net [xi]. Theorem A vector sublattice V of C*(Y) is dense in C*(Y) with the supremum norm iff (1) For two different equivalence classes [xi]* and [xj]*, there is an f in V such that lim[f(xi)] is not equal to lim[f(xj)]; (2) For each [xi]* and each positive real number t, there exists a g in V such that 1 - lim[g(xi)]/[(g)] is less than t, where [(g)] is the supremum norm of g. (Received September 12, 2014)

1106-46-1237 **Valentin Ferenczi** and **Christian Rosendal*** (rosendal.math@gmail.com), Mathematics, Statistics and Computer Science, University of Illinois at Chicago, 851 S. Morgan St., Chicago, IL 60607. *Maximal symmetry in Banach spaces.*

Mazur's rotation problem, though not appearing in the Scottish book but instead in Banach's monograph, remains one of the central unsolved problems of functional analysis dating back to this period of Polish mathematics.

The problems asks whether every separable Banach space whose isometry group acts transitively on the unit sphere must be euclidean, i.e., Hilbert space. This problem points to several aspects of the isometric theory of Banach spaces that are far from being well understood even in the case of Hilbert space, the common concept being that of maximal symmetry. We shall discuss various open problems and results in this direction. (Received September 11, 2014)

1106-46-1445 **Teffera M Asfaw*** (teffera6@vt.edu), Department of Mathematics, Virginia Tech, Blacksburg, VA 24061. *Variational inequality and surjectivity of noncoercive operators and application to nonlinear parabolic problems.* Preliminary report.

Let X be a real reflexive locally uniformly convex Banach space with locally uniformly convex dual X^*. New variational inequality and surjectivity results are obtained for noncoercive operators of the type $T+A+S$ where $T : X \supseteq D(T) \to 2^{X^*}$ and $A : X \supseteq D(A) \to 2^{X^*}$ are maximal monotone and $S : X \supseteq D(S) \to 2^{X^*}$ is bounded pseudomonotone. A positive answer for Nirenberg's problem is included for quasimonotone expansive mappings. The results are new and improve the corresponding theory concerning surjectivity of coercive operators of monotone type. The theory developed herein is applied to study existence of generalized solution(s) in $X = L^p(0,T;W_0^{1,p}(\Omega))$ (with suitable $p > 1$) of the parabolic problem

$$\begin{cases} \frac{\partial u}{\partial t} - \triangle_p u + g(x,u,\nabla u) = f & \text{in } (0,T)\times\Omega \\ u(t,x) = 0 & \text{in } (0,T)\times\partial\Omega \end{cases}$$

where f is a given function, Ω is nonempty, bounded and open subset of $\mathbb{R}^N$ and $g : \Omega\times\mathbb{R}\times\mathbb{R}^{\mathbb{N}} \to \mathbb{R}$ satisfies certain conditions.

(Received September 13, 2014)

1106-46-1494 **Roy M. Araiza*** (rogelio.m.araiza@gmail.com), **Heather Buyu** (heatheradongobuyu@yahoo.com), **Kimberly Duran** (kimalduran@gmail.com) and **Richard Morris** (richard.morris@utexas.edu). *A Classification of Two-Dimensional Operator Systems in M_2.* Preliminary report.

An operator system is a closed subspace of some $B(\mathcal{H})$, where $B(\mathcal{H})$ is a space of bounded linear operators on a Hilbert Space $\mathcal{H}$, such that the operator system is closed under the adjoint operation and contains the identity operator I. In the complex case it was then shown by C. Webster and S. Winkler that for operator systems with complex-valued entries, that any operator system is completely order isomorphic to a space of continuous matrix affine functions on a compact matrix convex set. A natural question then arises of whether this property will hold for operator systems with real number entries. We give concrete representations of real and complex two-dimensional operator systems in M_2, and elaborate on the relationship between these operator systems and two-dimensional spaces of continuous matrix affine functions on a compact matrix convex set. (Received September 15, 2014)

1106-46-1601 **George A. Elliott*** (elliott@math.toronto.edu), Department of Mathematics, University of Toronto, Toronto, Ontario M5S 2E4, Canada, and **Zhuang Niu**. *Well behaved dynamics.*

In the context of the classification of amenable C*-algebras, an important criterion for an algebra to be well behaved is that it be stable under tensoring with the so-called Jiang-Su C*-algebra. (Toms and Winter have conjectured that this is equivalent to certain other properties, at least in the simple case.)

Generalizing earlier work, by many authors, notably by Toms and Winter, the authors have shown that a simple C*-algebra arising from a dynamical system consisting of a homeomorphism of an infinite metrizable compact space is well behaved in this sense (i.e., Jiang-Su stable) if the dynamical system has mean dimension zero.

(It is not known if this condition is necessary. The condition is known to hold in the uniquely ergodic case, or if there are only countably many ergodic invariant measures.) (Received September 14, 2014)

1106-46-1619 **J. E. Pascoe*** (jpascoe@math.ucsd.edu), 9500 Gilman Drive # 0112, La Jolla, CA 92093-0112. *Using operator theory to measure the asymptotic behavior of Pick functions in two variables at infinity.*

A Pick function is an analytic function from the poly upper half plane to the upper half plane. Pick functions share much of the rich theory of Schur functions, analytic functions from the polydisk into the disk, since the disk is conformally equivalent to the upper half plane. Furthermore, in two variables, operator theoretic techniques are available due to Ando's inequality. Agler, Tully-Doyle and Young developed a theory of representations of Pick functions in two variables in terms of operator theory which reflect the asymptotic behavior at infinity. In the special case where the function satisfies

$$\lim_{s\to\infty} |f(is,is)| < \infty$$

the representation takes the form

$$f(z_1, z_2) = \langle (A - z_1 Y - z_2(1-Y))^{-1}\alpha, \alpha\rangle$$

where A is an unbounded self-adjoint operator, Y is a positive contraction and α is a vector, which can be viewed as an analogue of Nevanlinna's representation in one variable. Agler and McCarthy showed that higher degrees of regularity at infinity are reflected in a certain operator theoretic constuct, the Hankel vector moment sequence. We introduce Hankel vector moment sequences and show how they can be applied to develop a detailed theory of the asymptotic behavior of Pick functions at infinity. (Received September 14, 2014)

1106-46-1693 **Ilya Amburg*** (ida1@williams.edu) and **Thomas Garrity** (tgarrity@williams.edu). *Functional Analysis of Triangle Partition Maps, a Family of Multidimensional Continued Fraction Algorithms: Transfer Operators, Zeta-Likeness, and Special Functions.* Preliminary report.

The recently-developed family of triangle partition maps encompasses almost every well-known multidimensional continued fraction algorithm and contains a wealth of new ones. In direct analogue to the standard-continued-fraction Gauss-Kuzmin statistics arising from the functional analysis of the transfer operator associated with the Gauss map, we have studied the transfer operators and Gauss-Kuzmin statistics arising from triangle partition maps. We have explained why these transfer operators fall into two distinct classes, with one class giving rise to particularly nice zeta-like functions. Further, we have shown that the transfer operators associated with several triangle partition maps are nuclear of trace class zero and have also constructed Gauss-Kuzmin statistics for a handful of these maps. In our study of the functional analysis behind these transfer operators we have encountered many special functions, including the Lerch zeta, Bessel, and digamma functions, as well as Laguerre polynomials. (Received September 15, 2014)

1106-46-1754 **Qingying Bu** and **Byunghoon Lee*** (blee4@olemiss.edu), Department of Mathematics, University of Mississippi, Oxford, MS 38677. *On Positive Tensor Products of ℓ_p-spaces.*

For $1 \leqslant p_1, \cdots, p_n < \infty$, we characterize the main diagonals of the positive projective tensor product $\ell_{p_1}\hat{\otimes}_{|\pi|} \cdots\hat{\otimes}_{|\pi|}\ell_{p_n}$ and the positive injective tensor product $\ell_{p_1}\check{\otimes}_{|\epsilon|}\cdots\check{\otimes}_{|\epsilon|}\ell_{p_n}$. Then by using these two main diagonals, we characterize the reflexivity, the property of being Kantorovich-Banach spaces, and the property of being order continuous of $\ell_{p_1}\hat{\otimes}_{|\pi|}\cdots\hat{\otimes}_{|\pi|}\ell_{p_n}$ and $\ell_{p_1}\check{\otimes}_{|\epsilon|}\cdots\check{\otimes}_{|\epsilon|}\ell_{p_n}$, as well as the space of all regular n-linear forms on $\ell_{p_1}\times\cdots\times\ell_{p_n}$ and the space of all regular n-homogeneous polynomials on ℓ_p $(1 \leqslant p < \infty)$. (Received September 15, 2014)

1106-46-1762 **Martino Lupini*** (mlupini@yorku.ca). *The complexity of classification problems in operator algebras.*

I will present an overview on the complexity of several classification problems in operator algebras from the point of view of invariant complexity theory. (Received September 15, 2014)

1106-46-1785 **David P Blecher*** (dblecher@math.uh.edu), Department of Mathematics, University of Houston, Houston, TX 77204-3008. *The generalization of C*-algebra methods.* Preliminary report.

With Charles Read we have introduced and studied a new notion of (real) positivity in operator algebras, with an eye to extending certain C*-algebraic results, techniques, and theories to more general algebras. As motivation note that the 'completely' real positive maps on C*-algebras or operator systems are precisely the completely positive maps in the usual sense; however with real positivity one may develop a useful order theory for more general operator algebras (and operator spaces). This is intimately connected to new relationships between an operator algebra and the C*-algebra it generates. We report on the state of this theory, which is mostly joint work with Read, and will include new results along these lines joint with Matthew Neal. We emphasize connections with various C*-algebraic techniques initiated by Richard V. Kadison. (Received September 15, 2014)

1106-46-1869 **Christopher Michael Schwanke*** (cmschwan@olemiss.edu), University of Mississippi, Department of Mathematics, University, MS 38677, and **Gerard Buskes**. *Stolarsky Means and Fremlin Tensor Products.*

Using functional calculus, we introduce completions of Archimedean vector lattices with respect to continuous, real-valued functions on $\mathbb{R}^n$ that are positively homogeneous. Examples include the widely-studied Stolarsky and Gini means. By completing the Fremlin tensor product of real Archimedean vector lattices with respect to a particular Stolarsky mean, we prove the existence of a Fremlin tensor product for complex Archimedean vector lattices. (Received September 15, 2014)

1106-46-1977 **George A. Elliott*** (elliott@math.toronto.edu), Department of Mathematics, University of Toronto, Toronto, Ontario M5S 2E4, Canada, and **Zhuang Niu**, **Luis Santiago**, **Aaron Tikuisis** and **Wilhelm Winter**. *Some recent results related to the Toms-Winter conjecture.*

A major part of the Toms-Winter conjecture (concerning the existence of a robust well-behaved class of amenable, or nuclear, C*-algebras) is that a Jiang-Su stable finite separable amenable simple unital C*-algebra should have finite decomposition rank.

This is known if the algebra is approximately homogeneous (AH), and also if it belongs to the class of approximately subhomogeneous (ASH) C*-algebras recently classified by Gong, Lin, and Niu (perhaps all Jiang-Su stable simple unital ASH algebras). It is also known if the space of traces is a Bauer simplex and the algebra has a quasidiagonal representation realizing any given trace (Matui and Sato; Bosa, Brown, Sato, Tikuisis, White, and Winter).

The present authors have shown this for any Jiang-Su stable ASH C*-algebra (no condition on traces, and even not assuming that the algebra is simple or unital).

In fact, the proof is valid for a locally subhomogeneous C*-algebra (not known to be an inductive limit), and this is of interest since the tensor product of a simple C*-algebra arising from a homeomorphism of a metrizable compact space with a UHF algebra is locally subhomogeneous, and so as a consequence (since a UHF algebra is Jiang-Su stable), has finite decomposition rank. (Received September 15, 2014)

1106-46-2005 **Stephan C Roberts*** (scrober2@olemiss.edu) and **Gerard Buskes**. *Adjoints of Orthogonally Additive Polynomials.*

We present, using new techniques, results on Aron-Berner extensions of n-homogeneous orthogonally additive polynomials of order bounded variation between arbitrary Archimedean vector lattices. (Received September 16, 2014)

1106-46-2016 **Natasha Blitvić*** (nblitvic@indiana.edu), Department of Mathematics, Rawles Hall, Indiana University, Bloomington, IN 47405, and **Todd Kemp** (tkemp@math.ucsd.edu), Department of Mathematics, AP&M, UC San Diego, La Jolla, CA 92093. *Segal–Bargmann Analysis in Deformed Gaussian Algebras.* Preliminary report.

The classical Segal-Bargmann transform is a unitary isomorphism between the L^2 space of the Gaussian measure on $\mathbb{R}^d$ and the space of holomorphic functions on $\mathbb{C}^d$ that are square-integrable with respect to the complex Gaussian measure. An analogous construction, due to Biane, is available in the setting of non-commutative L^2

spaces involving free semicircular and circular systems of Voiculescu, and further generalizes to the q-deformed setting of Bożejko and Speicher, as shown by Kemp. The Segal–Bargmann transform was recently extended by the present authors to the setting of non-tracial generalization of the q-Gaussian spaces in a manner that both complements and contrasts with some related constructions in mathematical physics. We will review the necessary background and discuss new results in this direction. (Received September 15, 2014)

1106-46-2018 **Brent Nelson*** (`bnelson6@math.ucla.edu`). *Free monotone transport without a trace.*
Classical transport is a map $T : X \to Z$ between probability spaces (X, μ) and (Z, ν) such that $T_*\mu = \nu$. Consequently, $f \mapsto f \circ T$ provides an integral preserving embedding of $L^\infty(Z, \nu)$ into $L^\infty(X, \mu)$. Free transport extends this idea to non-commutative probability spaces (i.e. pairs (A, φ) of von Neumann or C^*-algebras and states) to produce embeddings and even isomorphisms between non-commutative probability spaces. In this talk, we will discuss how to construct non-tracial transport by solving a non-commutative differential equation known as the Schwinger-Dyson equation and, time permitting, applications to q-deformed Araki-Woods algebras and finite depth subfactor planar algebras. (Received September 15, 2014)

1106-46-2146 **Tatsuya Tate*** (`tate@math.tohoku.ac.jp`). *Powers of certain quantum walks.* Preliminary report.
The notion of quantum walks are defined as a non-commutative analogue of the usual random walks and they are investigated mainly in quantum physics, information science, combinatorics and probability theory. As in the theory of random walks, one of the main issues for the quantum walks is to find various asymptotic properties of transition probabilities, which are defined by using the powers of a unitary operator expressing a quantum walk, and hence it is important to understand powers of quantum walks. In this talk an effective and concrete formulas for the powers of certain quantum walks are given. These formulas involve the Chebyshev polynomials and it can be used to deduce weak limit distributions. Weak limit distributions for the class of quantum walks which will be discussed in this talk has been already known before. However it would be rather important to get precise and effective formulas for the powers itself to clarify the qualitative structures of quantum walks. In the talk, some relations between these formulas and the affine Weyl group of type A are also discussed. (Received September 15, 2014)

1106-46-2235 **Karen R. Strung***, ul. Śniadeckich 8, 00-656 Warsaw, Poland. C*-*algebras associated to minimal dynamical systems.*
I will discuss the classification problem for C*-algebras associated to minimal dynamical systems on compact metrizable spaces. While these are always simple, separable, unital and nuclear, in full generality they are not classifiable by the K-theoretic Elliott invariants. Nevertheless, the problem appears tractable in case the minimal dynamical system has mean dimension zero. I will discuss known results and their techniques, why these are not enough to cover all examples, and possible ways forward towards more classification results. (Received September 16, 2014)

1106-46-2237 **Fumio Hiroshima** (`hiroshima@math.kyushu-u.ac.jp`), 744 Motooka, Nishi-ku, Fukuoka, Fukuoka 8190395, Japan, and **Susumu Osawa*** (`osawa@math.sci.hokudai.ac.jp`), 8 Nishi Kita10jyou Kita-ku, Sapporo, Hokkaido 0600810, Japan. *Mass Renormalization in the Nelson Model.*
The asymptotic behavior of the so-called effective mass m_{eff} of the Nelson model in the scalar quantum field theory with the space dimension $d \geq 3$ is considered. The Nelson model is defined as a self-adjoint operator by introducing ultraviolet cutoff $\Lambda > 0$. Let $\alpha \in \mathbb{R}$ be a coupling constant. It is shown that for sufficiently small $|\alpha|$,

$$m_{\text{eff}}/m = 1 + \sum_{n=1}^{\infty} a_n(\Lambda)\alpha^{2n},$$

where m denotes a bare mass. It is shown that for $d \leq 2$,

$$\limsup_{\Lambda\to\infty} |a_n(\Lambda)| < \infty,$$

and for $d = 3$,

$$\lim_{\Lambda\to\infty} |a_n(\Lambda)|/(\log\Lambda)^{n-1} < \infty$$

holds. (Received September 16, 2014)

1106-46-2260 **Alexander A Katz*** (katza@stjohns.edu), Dep. of Math&CS, St. John's College of LAS, St. John's University, 8000 Utopia Parkway, SJH 334-G, Queens, NY 11439. *On one theorem of Kadison for locally C*-algebras.*

We generalize a well known theorem of Kadison by establishing that a locally C*-homomorphism of a locally W*-algebra onto a locally C*-algebra of the same type is a sum of a locally *-homomorphism and a locally *-anti-homomorphism. (Received September 16, 2014)

1106-46-2286 **Alexander A Katz** (katza@stjohns.edu), Dep. of Math&CS, St. John's College of LAS, St. John's University, 8000 Utopia Parkway, SJH 334-G, Queens, NY 11439, and **Oleg Friedman*** (friedman001@yahoo.com), Dep. of Math Sc., U of South Africa, RSA /, Dep. of Math., Lander College for Men /, Touro College, Kew Gardens Hills, NY 11367. *On Gelfand-Naimark type theorem for real locally C*-algebras.*

We show that for each real locally C*-algebra A (projective limit of a projective family of real C*-algebras) of a given type there exists a real locally Hilbert space H (inductive limit of real Hilbert spaces) such that A is locally isometrically *-isomorphic to a closed in projective topology *-subalgebra of the real locally C*-algebra L(H) of continuous linear operators on H. (Received September 16, 2014)

1106-46-2425 **Wutiphol Sintunavarat*** (poom_teun@hotmail.com), Khlong Luang, Pathumthani, 12121, Thailand. *A new approach to α-ψ-contractive mappings along with multiplicative distances and generalized Ulam-Hyers stability, well-posedness and limit shadowing results.*

In this talk, we introduce the new concept of α-ψ-contractive mappings along with multiplicative distances and give example to show that our concept is different from the concept corresponding existing in the literature. We also give fixed point theorems for α-ψ-contractive mappings in multiplicative metric spaces and give some example which support our main result while previous results in literature are not applicable. Moreover, we study the generalized Ulam-Hyers stability, the well-posedness and the limit shadowing for fixed point problems satisfy our conditions. (Received September 16, 2014)

1106-46-2447 **Debendra P Banjade*** (dpbanjade@coastal.edu), Coastal Carolina University, Department of Mathematics, P.O. Box 261954, Conway, SC 29528, and **Caleb D Holloway** and **Tavan T Trent**. *A Generalized Wolff's Ideal Theorem on Certain Subalgebras of $H^\infty(\mathbb{D})$.*

In 1962, L. Carleson proved his celebrated Corona Theorem characterizing when a finitely generated ideal of $H^\infty(\mathbb{D})$ is all of $H^\infty(\mathbb{D})$. Later, in 1980, T. Wolff extended Carleson's result and partially generalized the Corona Theorem in $H^\infty(\mathbb{D})$. More recently, S. Treil provided the best known sufficient condition for the generalized Corona Theorem in $H^\infty(\mathbb{D})$. In this talk, we prove the generalized Wolff's Ideal Theorem on certain uniformly closed subalgebras of $H^\infty(\mathbb{D})$ on which the Corona Theorem is already known to hold.

This talk is based on a joint work with Caleb Holloway and Tavan T. Trent. (Received September 16, 2014)

1106-46-2489 **Matthew McBride*** (mmcbride@math.ou.edu), **Slawomir Klimek**, **Sumedha Rathnayake** and **Kaoru Sakai**. *The Quantum Pair of Pants.*

The goal of this talk is to define a specific C^*-algebra and make a case that this algebra is a good candidate for the quantum pair of pants. (Received September 16, 2014)

1106-46-2856 **Sofya Masharipova*** (sofya.masharipova@ashford.edu), 400 North Bluff Blvd, Dept of Mathematics and Computer Science, Ashford University, Clinton, IA 52732, and **Shukhrat Usmanov** (shukhrat.usmanov@ashford.edu), 400 North Bluff Blvd, Dept of Mathematics and Computer Science, Ashford University, Clinton, IA 52732. *Functional calculus and spectral theorem for self-adjoint operators on Pontrjagin P_1 space with indefinite metric.* Preliminary report.

Functional calculus for self-adjoint operators (in particular, of classes 3a and 1 in Shulman's classification) on Pontrjagin P_1 space with indefinite metric is considered. Spectral theorem for such operators is proven.
(Received September 16, 2014)

1106-46-2890 **L. Hall*** (lhall10@asu.edu), 730 E McKellips Rd. Apartment C-326, Tempe, AZ 85281. *The Union of Frame Theoretic and Gegenbauer Reprojection Techniques to Improve Image Construction Rates.* Preliminary report.

In many image reconstruction processes, data are collected in the frequency domain. Constraints on the procedure, especially time and patient behavior, lead to image data that is both finite and nonuniformly spaced, which together lead to poor reconstruction by conventional uniform methods. Furthermore, the recovered image

experiences the Gibbs Phenomenon, which descrives the tendency of a Fourier Series to diverge at discontinuities and converge only slowly elsewhere. Separately, successful methods have been developed either to rectify the series expansion process, or to construct a series which provides faster convergence rates. Joining these processes appears to be a straigntforward approach to quickly recover images from the collected data, however there are open questions regarding these transformations and how they behave analytically. These questions are the subject of this research. (Received September 17, 2014)

47 ► Operator theory

1106-47-37 **Xavier Alexius Udo-utun*** (xvior@yahoo.com), Department of Mathematics and Statistics, University of Uyo, Uyo, Nigeria. *On unification of fixed point techniques - Applications of $(\delta, k)-$weak contractions.*

Author (Udo-utun Fixed Point Theory and Applications 2014, 2014:65) derived a novel generalizing property of $F-$contractions introduced recently by Wardowski (Fixed Point Theory and Applications 2012:94, 2012) which applicability yields asymptotic fixed point theorems for contractive, nonexpansive and all Lipschitzian operators sharing the property. Attempt is made to extend applicability to a more general class of continuous and certain discontinuous operators in Banach and metric spaces as a unifying significance of the property and the notion of $(\delta, k)-$weak contractions introduced earlier by Berinde (Carpath. J. Math. 19(1):7-22, 2003; Nonlinear Anal. Forum 9(1):43-53, 2004). Interesting examples are illustrated. (Received May 12, 2014)

1106-47-50 **Marlene Frigon*** (frigon@dms.umontreal.ca), University of Montreal, Department mathematics and statistics, C.P. 6128, succ. centre-ville, Montreal, Quebec H3C 3J7, Canada. *Fixed point results for multivalued contractions on a metric space with a graph and applications.*

We present fixed point results for multivalued maps defined on a complete metric space endowed with a directed graph, called weak G-contractions, which send connected points into connected points and contract the length of paths. We also present applications to graph-directed iterated function systems. More precisely, a fixed point result for G-contractions is applied to obtain more information on the attractor K of a graph-directed iterated function system. (Received May 30, 2014)

1106-47-229 **Monther Rashed Alfuraidan*** (monther@kfupm.edu.sa), P O Box 1285, Dhahran, Eastern 31261, Saudi Arabia. *Caristi Fixed Point Theorem in Metric Spaces with a Graph.*

We discuss the Caristi's fixed point theorem for mappings defined on a metric space endowed with a graph. It extends some recent works on the extension of Banach Contraction Principle to metric spaces with graph. (Received August 13, 2014)

1106-47-281 **Gelu F Popescu*** (gelu.popescu@utsa.edu). *Euler Characteristic on Noncommutative Polyballs.*

We introduce and study the Euler characteristic associated with algebraic modules generated by arbitrary elements of certain noncommutative polyballs. We provide several asymptotic formulas and prove some of its basic properties. We show that the Euler characteristic is a complete unitary invariant for the finite rank Beurling type invariant subspaces of the tensor product of full Fock spaces $F^2(H_{n_1}) \otimes \cdots \otimes F^2(H_{n_k})$, and prove that its range coincides with the interval $[0, \infty)$. We obtain an analogue of Arveson's version of the Gauss-Bonnet-Chern theorem from Riemannian geometry, which connects the curvature to the Euler characteristic. In particular, we prove that if M is an invariant subspace of $F^2(H_{n_1}) \otimes \cdots \otimes F^2(H_{n_k})$, $n_i \geq 2$, which is graded (generated by multi-homogeneous polynomials), then the curvature and the Euler characteristic of the orthocomplement of M coincide. (Received August 19, 2014)

1106-47-288 **William T Ross*** (wross@richmond.edu), Department of Mathematics, University of Richmond, Richmond, VA 23173. *Concrete de Branges-Rovnyak spaces.* Preliminary report.

The de Branges-Rovnyak spaces are well-known spaces of analytic functions on the open unit disk which are used to model certain types of contraction operators on Hilbert spaces. Though these spaces are useful, there is not a lot known about their exact content. Exactly what is in a de Branges-Rovnyak space? In this joint with with Emmanuel Fricain and Andreas Hartmann, we answer this question for certain types of these spaces. (Received August 19, 2014)

1106-47-297 **Elias G. Katsoulis*** (katsoulise@ecu.edu), Department of Mathematics, East Carolina University, Greenville, NC 27858. *Local maps and the representation theory of operator algebras.* Preliminary report.

Using representation theory techniques, we study local multipliers and local derivations on various non-selfadjoint operator algebras. (Received August 27, 2014)

1106-47-440 **Philip M Gipson*** (s-pgipson1@math.unl.edu), Department of Mathematics, 203 Avery Hall, PO BOX 880130, Lincoln, NE 68588. *Invariant Basis Number for C^*-Algebras.*

We develop the ring theoretic notion of Invariant Basis Number (BN) in the context of C^*-algebras and their modules. A characterization for unital C^*-algebras with IBN is given in K-theoretic terms and permanence properties of IBN are considered. We will also explore C^*-algebras without IBN and describe their structural information in terms of a quantity termed the Basis Type. Universal objects, permanence properties, and existence results for Basis Types are given. Connections to graph C^*-algebras and Leavitt Path Algebras are present and will be discussed. (Received August 28, 2014)

1106-47-447 **Zeljko Cuckovic***, Department of Mathematics and Statistics, University of Toledo, 2801 W. Bancroft Street, Toledo, OH 43606, and **Sonmez Sahutoglu**. *Essential norm estimates for Hankel operators on convex domains in $\mathbb{C}^2$.*

Let $\Omega \subset \mathbb{C}^2$ be a bounded convex domain with C^1-smooth boundary and $\varphi \in C^1(\overline{\Omega})$ that is harmonic on non-trivial disks in the boundary. We estimate the essential norm of the Hankel operator H_φ in terms of the $\overline{\partial}$ derivatives of φ "along" the disks in the boundary. (This is a joint work with Sonmez Sahutoglu) (Received August 28, 2014)

1106-47-463 **Niels Meesschaert*** (niels.meesschaert@wis.kuleuven.be) and **Stefaan Vaes**. *Partial classification of the Baumslag-Solitar group von Neumann algebras.*

For all $n, m \in \mathbb{Z} \setminus \{0\}$, the *Baumslag-Solitar group* $\mathrm{BS}(n, m)$ is defined by the presentation

$$\mathrm{BS}(n, m) := \langle a, b \mid ba^n b^{-1} = a^m \rangle \ .$$

These groups were introduced by Baumslag and Solitar to provide the first examples of finitely presented non-Hopfian groups. We prove that the rational number $|n/m|$ is an invariant of the group von Neumann algebra of the Baumslag-Solitar group $\mathrm{BS}(n, m)$. More precisely, if $L(\mathrm{BS}(n, m))$ is isomorphic with $L(\mathrm{BS}(n', m'))$, then $|n'/m'| = |n/m|^{\pm 1}$. We obtain this result by associating to abelian, but not maximal abelian, subalgebras of a II_1 factor, an equivalence relation that can be of type III. In particular, we associate to $L(\mathrm{BS}(n, m))$ a canonical equivalence relation of type $\mathrm{III}_{|n/m|}$. (Received August 29, 2014)

1106-47-506 **Jennifer Good*** (jennifer-good@uiowa.edu), University of Iowa, Department of Mathematics, 14 MacLean Hall, Iowa City, IA 52242-1419. *Pick Interpolation in a Weighted Noncommutative Setting.*

Inspired by Popescu's work with noncommutative varieties and related constructs, Muhly and Solel recently extended their work on Hardy algebras of W^*-correspondences to accommodate operator-valued weights. Many classical notions, for instance the interpolation results of Nevanlinna and Pick, have appropriate generalization in this setting. We will explore several of these ideas. (Received September 05, 2014)

1106-47-553 **Erin Griesenauer*** (erin-griesenauer@uiowa.edu), Department of Mathematics, University of Iowa, Iowa City, IA 52242-1419, and **Paul S. Muhly** and **Baruch Solel**. *Cross Section Algebras of Holomorphic Matrix Bundles.*

We discuss algebras of cross sections of holomorphic $M_n(\mathbb{C})$ - fibre bundles defined over Stein compact subsets of complex manifolds, and calculate their C^*-envelopes in the sense of Arveson. Using techniques from the theory of polynomial identity algebras and geometric invariant theory, we apply our analysis to calculate the C^*-envelopes of algebras built from generic matrices and trace algebras that arise in noncommutative function theory. (Received September 02, 2014)

1106-47-640 **Kelly Bickel*** (kelly.bickel@bucknell.edu) and **Brett D. Wick**. *Well-Localized Operators on Matrix-Weighted L^2 Spaces.*

In this talk, we consider "almost diagonal" operators, called well-localized operators, which map $L^2(\mathbb{R}, \mathbb{R}^n)$ to $L^2(\mathbb{R}, \mathbb{R}^n)$. Such operators include both matrix-valued Haar multipliers and dyadic shifts. In this setting, we obtain a T(1) Theorem characterizing the boundedness of well-localized operators between $L^2(W)$ and $L^2(V)$, where W and V are $n \times n$ matrix A_2 weights. This result generalizes a scalar T(1) theorem due to Nazarov-Treil-Volberg, which played a key role in the proof of the A_2 conjecture for dyadic shifts and related operators. (Received September 03, 2014)

1106-47-651 **Erin Griesenauer** and **Paul S. Muhly***, Department of Mathematics, University of Iowa, Iowa City, IA 52242-1419, and **Baruch Solel**. *PI and GIT Methods in Free Analysis.*

In this largely expository talk, we describe some ways in which methods from Polynomial Identity (PI) Algebra and Geometric Invariant Theory (GIT) can illuminate structures in noncommutative function theory. In particular, we provide background for Erin Griesenauer's talk in this session. (Received September 04, 2014)

1106-47-755 **Joseph A Ball*** (joball@math.vt.edu), Department of Mathematics, 460 McBryde Hall, 225 Stanger Street, Blacksburg, VA 24060-0123, and **Vladimir Bolotnikov**. *Dilation and functional-model theory for Hilbert space noncommutative n-hypercontractive operator tuples.* Preliminary report.

The Sz.-Nagy-Foias model theory for $C_{\cdot 0}$ contraction operators combined with the Beurling-Lax theorem establishes a correspondence between any two of the following four notions: (1) shift-invariant subspaces, (2) operator-inner functions, (3) conservative discrete-time input/state/output linear systems, and (4) $C_{\cdot 0}$ Hilbert-space contraction operators. Recent work of Olofsson and of the authors has extended these ideas to the weighted Bergman space setting, where the notion of $C_{\cdot 0}$ contraction operator T is replaced by a $C_{\cdot 0}$ $*$-n-hypercontraction (so $\sum_{j=0}^{k} \binom{k}{j}(-1)^j T^j T^{*j} \succeq 0$ for $k = 1, \ldots, n$). In this talk we discuss a model theory for freely noncommutative $C_{\cdot 0}$ n-hypercontractive operator tuples $T = (T_1, \ldots, T_d)$ on a Hilbert space $\mathcal{H}$. The special case $n = 1$ of the construction collapses to the Popescu generalized Sz.-Nagy-Foias dilation and model theory for a $C_{\cdot 0}$ row-contractive operator tuple. (Received September 05, 2014)

1106-47-788 **Joseph A Ball*** (joball@math.vt.edu), Department of Mathematics, Virginia Tech, 460 McBryde Hall, 225 Stanger Street, Blacksburg, VA 24061-0123. *Nevanlinna-Pick interpolation for generalized Schur-class functions: a survey of recent developments.* Preliminary report.

The theorem of Nevanlinna-Pick from the early 20th century says: *given interpolation nodes $z_1, \ldots, z_n$ in the unit disk $\mathbb{D}$ and complex numbers $w_1, \ldots, w_n$, there is a holomorphic function $s\colon \mathbb{D} \to \overline{\mathbb{D}}$ meeting the interpolation conditions $s(z_i) = w_i$ for $i = 1, \ldots, N$ if and only if the associated Pick matrix $\mathbb{P} = \left[\frac{1-w_i\overline{w_j}}{1-z_i\overline{z_j}}\right]$ is positive semidefinite.* It was only much later that the subject got a major boost due to the introduction of reproducing kernel and operator theory techniques beginning roughly in the 1960s. Additional stimulus came in the 1980s for extension to matrix and operator-valued settings due to intimate connections with systems engineering (especially H^∞-control theory). There are now emerging theories of Nevanlinna-Pick interpolation for multivariable settings as well as generalized Schur classes consisting of "noncommutative functions". The talk will survey these various settings for Nevanlinna-Pick interpolation and explain how some of the most recent developments can be seen to be already implicit in some of the earlier work on more prosaic settings. (Received September 06, 2014)

1106-47-797 **G. Marx*** (marxg@vt.edu), **J. A. Ball** and **V. Vinnikov**. *Complete Pick kernels: the noncommutative setting.*

Given a positive kernel K with associated reproducing kernel Hilbert space $\mathcal{H}(K)$, one says that K is a complete Pick kernel if positivity of a single Pick matrix associated with the interpolation data is always both necessary and sufficient for solvability of the associated matrix multiplier interpolation problem. It is now well known that the Drury-Arveson kernel $k_d(z, w) = \frac{1}{1-z_1\overline{w}_1-\cdots-z_d\overline{w}_d}$ on the unit ball $\mathbb{B}^d \subset \mathbb{C}^d$ has a certain universal property with respect to irreducible complete Pick kernels.

We discuss a noncommutative analogue of positive kernel and associated reproducing kernel Hilbert space and formulate the interpolation problem for contractive multipliers in this setting. A particular such kernel (called the noncommutative Szegő kernel) has associated reproducing kernel Hilbert space equal to the Fock space appearing in Popescu's Sz-Nagy-Foias model theory for row contractions. We show that this noncommutative Szegő kernel has the complete Pick property and is a likely candidate for having the universal property with respect to arbitrary noncommutative complete Pick kernels. (Received September 09, 2014)

1106-47-801 **Paul S. Muhly** and **Baruch Solel*** (mabaruch@tx.technion.ac.il), Department of Mathematics, Technion, 32000 Haifa, Israel. *Matricial function theory and weighted shifts.*

Let $H^\infty(E)$ be the Hardy algebra of a W^*-correspondence E over a W^*-algebra M. These algebras are generated by a copy of M and shifts (defined by the elements of E). Each element $F \in H^\infty(E)$ gives rise to a family $\{\widehat{F}_\sigma\}$ of analytic operator valued functions where σ runs over the normal representations of M and $\widehat{F}_\sigma$ is defined on the (open) unit ball of the operator space $E^{\sigma *}$ (associated with E and σ). Such a family exhibit "matricial structure" that we studied in previous works (inspired by works of Joseph Taylor, Kaliuzhnyi-Verbovetskyi and Vinnikov , D. Voiculescu and others).

In this talk I will show that one can study matricial families of operator-valued functions defined on more general matricial sets (not necessarily unit balls) by studying Hardy algebras generated by a copy of M and *weighted* shifts. This work generalizes some results of G. Popescu. (Received September 07, 2014)

1106-47-812 **Anna Skripka*** (askripka@unm.edu). *Perturbation of operator functions.* Preliminary report.

We will discuss recent results on approximation of perturbed values of operator functions by initial data. (Received September 07, 2014)

1106-47-819 **Matthew Fleeman*** (mcfleema@mail.usf.edu) and **Dmitry Khavinson** (dkhavins@usf.edu). *Extremal Domains for Self-Commutators in the Bergman Space.*

In recent work, Olsen and Reguera have shown that Putnam's inequality for the norm of self-commutators can be improved by a factor of $\frac{1}{2}$ for Toeplitz operators with analytic symbol φ acting on the Bergman space $A^2(\Omega)$ when φ is univalent in Ω. This improved upper bound is sharp when $\varphi(\Omega)$ is a disk. In this talk we show that disks are the only domains for which the upper bound is attained, and explore situations when the symbol is not univalent. (Received September 07, 2014)

1106-47-874 **Raphael Clouatre** and **Kenneth R. Davidson*** (krdavids@uwaterloo.ca), Pure Math. Dept., University of Waterloo, 200 University Ave. W., Waterloo, ON N2L3G1, Canada. *The dual of the continuous multipliers on Drury-Arveson space.* Preliminary report.

Let $\mathcal{A}_d$ denote the norm closed algebra generated by the multiplication operators by the coordinate functions z_i on Drury-Arveson space H^2_d for $d \geq 2$. We identify the dual and second dual of $\mathcal{A}_d$ and of $\mathcal{A}_d/\mathcal{J}$ where $\mathcal{J}$ is a closed ideal. This is applied to obtain some information about the dilations of commuting row contractions. (Received September 08, 2014)

1106-47-877 **Antoine Julien** (antoine.julien@math.ntnu.no) and **Ian F. Putnam*** (ifputnam@uvic.ca), P.O.Box 3060 STN CSC, Victoria, B.C. V8W 3R4, Canada. *Spectral triples for subshifts.* Preliminary report.

Motivated by examples of differential operators, Alain Connes introduced the notion of a spectral triple. Despite the distinct contrast with manifolds, a number of interesting examples have been found for algebras of functions on a Cantor set and algebras of operators associated with dynamical systems on the Cantor set. Here, we present a new construction specific to the dynamics of subshifts. Properties of the spectral triples vary quite wildly with the class of subshift. (Received September 08, 2014)

1106-47-879 **J William Helton** (helton@math.ucsd.edu), **Igor Klep** (igor.klep@auckland.ac.nz), **Scott McCullough*** (sam@ufl.edu) and **Markus Schweighofer** (markus.schweighofer@uni-konstanz.de). *Dilating tuples of selfadjoint matrices to commuting tuples of selfadjoint operators.* Preliminary report.

The problem of dilating, up to a constant, a tuple of symmetric matrices to to a tuple of commuting selfadjoint contractive operators on Hilbert space is considered. For the purposes here, an operator T on a Hilbert space H dilates to an operator J on a Hilbert space K if H is a subspace of K and T=PJP. Here P is the orthogonal projection of K onto H. Fix a positive integer d and let C(r) denote the collection of symmetric d by d matrices of norm at most r. The optimal k(d) for which there exists a Hilbert space K and family F of commuting selfadjoint contractions on K such that the collection C(k(d)) simultaneously dilates to F is identified via an explicit construction. Connections with matrix cube and free spectrahedral inclusion problems will be discussed as time permits. The work is joint with Bill Helton, Igor Klep and Markus Schweighofer. (Received September 08, 2014)

1106-47-884 **J William Helton** (helton@math.ucsd.edu), **Igor Klep** (igor.klep@auckland.ac.nz), **Scott McCullough*** (sam@ufl.edu) and **Markus Schweighofer** (markus.schweighofer@uni-konstanz.de). *The matrix cube, dilations, linear matrix inequalities and probability.*

Ben-Tal and Nemirovski introduce the matrix cube problem and connect it to semidefinite programming with interval uncertainty and quadratic Lyapunov stability analysis and synthesis. A principal result of theirs is the identification of a computable, but not explicit, error estimate for a natural relaxation of the problem. We show their relaxation has a natural interpretation - one that readily generalizes to the problem of free spectrahedral inclusion - in the theory of completely positive maps and operator systems. Further, the Ben-Tal Nemirovski estimate is sharp; the estimate itself arises naturally as a consequence of a dilation theorem; and, in the process of identifying an analytic expression for the bound, we establish probabilistic results related to Simmon's theorem for the binomial (beta) distribution. The work is joint with Bill Helton, Igor Klep and Markus Schweighofer. (Received September 08, 2014)

1106-47-904 **Greg Knese*** (geknese@math.wustl.edu), Washington University in St. Louis, One Brookings Drive, Campus Box 1146, Dept. of Mathematics, St. Louis, MO 63130.
Algebraic and analytic structure of stable polynomials. Preliminary report.

Stable polynomials, those with no zeros on some specified set such as the bidisk, appear in many of areas of mathematics, yet many basic questions about them and associated rational functions with a stable polynomial in the denominator do not have an adequate theory to address them. For example, when is such a rational function in two variables in L^2 of the two-torus? It turns out that a blend of Hilbert space theory and algebraic curve theory can be used to answer this and other questions. The work also sheds light on the structure of rational inner functions on the bidisk. (Received September 08, 2014)

1106-47-1042 **Matthew Kennedy*** (mkennedy@math.carleton.ca), School of Mathematics and Statistics, Carleton University, 1125 Colonel By Drive, Ottawa, Ontario K1S 5B6, Canada.
A Lebesgue-type decomposition theorem for linear functionals on noncommutative function spaces.

I will discuss a Lebesgue-type decomposition theorem for certain noncommutative function spaces. This can be seen as a non-self-adjoint analogue of Takesaki's decomposition theorem for linear functionals on von Neumann algebras, in the sense that every bounded linear functional is decomposed into "absolutely continuous" and "singular" parts. This result has some interesting applications in noncommutative function theory, for example, leading to a noncommutative generalization of the classical F. & M. Riesz theorem. But it also has applications in the commutative setting, for example, leading to a proof that multiplier algebras on complete Nevanlinna-Pick spaces, including the Drury-Arveson space, have unique preduals.

This is joint work with Dilian Yang. (Received September 10, 2014)

1106-47-1044 **Carlos M. Ortiz-Marrero*** (cortiz@math.uh.edu) and **Vern I. Paulsen** (vern@math.uh.edu). *Lovász Theta Type Norms and Operator Systems.* Preliminary report.

Two graphs are isomorphic if and only if their corresponding operator systems are unitally completely order isomorphic. In this talk we examine how this extra structure that comes from the operator system can be used to say something new about a graph via this correspondence. We found that certain quotient norms that arise from studying the operator system of a graph give rise to a new family of parameters of a graph. We then show basic properties about these norms, write down explicitly how to compute them via a semidefinte program, and discuss their similarities to the Lovász theta function. Finally, we explore a particular parameter in this family and establish a new graph theoretic condition. (Received September 10, 2014)

1106-47-1262 **Remi Boutonnet***, Dept. Of Mathematics, University of California San Diego, 9500 Gilman Drive, MC0112, LA JOLLA, CA 92093. *Maximal amenable von Neumann subalgebras arising from maximal amenable subgroups.*

Consider a maximal amenable subgroup H in a discrete countable group G. In this talk I will give a general condition implying that the von Neumann subalgebra LH is still maximal amenable inside LG. The condition is expressed in terms of H-invariant measures on some compact G-space. As an example I will show that the subgroup of upper triangular matrices inside $\mathrm{SL}(n, \mathbb{Z})$ gives rise to a maximal amenable subalgebra. This talk is based on a joint work with Alessandro Carderi. (Received September 11, 2014)

1106-47-1271 **George R. Exner*** (exner@bucknell.edu), Department of Mathematics, Bucknell University, Moore Avenue, Lewisburg, PA 17837, and **Joo Young Jin**, **Il Bong Jung** and **Mi Ryeong Lee**. *Weighted shifts induced by Hamburger moment sequences.* Preliminary report.

We consider weighted shift operators on Hilbert space, and, weakening properties arising from positivity of Hankel moment matrices associated with k-hyponormality, subnormality, and Hausdorff moment sequences, consider some new properties $H(n)$ $(n = 1, 2, ...)$ and a Hamburger-type weighted shift which are associated with a Hamburger moment sequence. We discuss examples to show the various $H(n)$ are distinct; flatness, backward n-step extensions and perturbations of weighted shifts; and, given three initial weights $\alpha_0, \alpha_1, \alpha_2$ with $\alpha_0 \leq \alpha_2 < \alpha_1$, we produce a completion: a weighted shift of Hamburger-type but not subnormal, extending a (subnormal) completion by Stampfli in the case $\alpha_0 < \alpha_1 < \alpha_2$. (Received September 11, 2014)

1106-47-1301 **David R. Larson*** (larson@math.tamu.edu), Department of Mathematics, College Station, TX 77845, and **Deguang Han**, **Bei Liu** and **Rui Liu**. *Operator-valued measures, dilations and frame theory.*

In a recent article (AMS memoir) we developed a general dilation theory for operator valued measures and maps between von Neumann algebras that include maps that are not necessarily completely bounded. In a subsequent article (JFA) we obtained some results for dilations of operator-valued systems of imprimitivity. Our main results state that any operator-valued measure, not necessarily completely bounded, always has a dilation to a projection-valued measure acting on a Banach space, and every bounded linear map, again not necessarily completely bounded, on a Banach algebra has a bounded homomorphism dilation acting on a Banach space. These results lead to some new connections between frame theory and operator algebras. (Received September 12, 2014)

1106-47-1318 **Akram Aldroubi*** (akram.aldroubi@vanderbilt.edu), **Carlos Cabrelli**, **Ursula Molter** and **Sui Tang**. *Dynamical sampling in Hilbert spaces.*

Let $Y = \{f(i), Af(i), \dots, A^{l_i}f(i) : i \in \Omega\}$, where A is a bounded operator on $\ell^2(I)$. The problem under consideration is to find necessary and sufficient conditions on A, Ω, l_i in order to recover any $f \in \ell^2(I)$ from the measurements Y. This is the so called dynamical sampling problem in which we seek to recover a function f by combining coarse samples of f and its futures states $A^l f$, $l = 1, \dots, l_i$. We solve this problem in finite dimensional spaces, and for a large class of self adjoint operators in infinite dimensional spaces. (Received September 12, 2014)

1106-47-1371 **Adam S Orenstein*** (adamoren@buffalo.edu), 244 Mathematics Building, University at Buffalo, Buffalo, NY 14260. *Symmetric normed ideals and symmetric norming functions with examples and motivation.*

There has been an increasing interest in symmetrically-normed ideals in recent years. A widely known example is the Schatten p-class for any $p > 0$. In this talk, the concept of a symmetrically-normed ideal and the related concept of a symmetric norming function will be defined. Some useful properties and theorems, such as Fan's Theorem, will be presented. We will also see some examples besides the Schatten p-classes. After this, the motivation for studying symmetrically-normed ideals will be presented. (Received September 12, 2014)

1106-47-1389 **Waleed K. Al-Rawashdeh*** (walrawashdeh@mtech.edu), Montana Tech, 1300 West Park Street, Butte, MT 59701. *Composition Operators on Generalized Weighted Nevanlinna Class.*

Let φ be an analytic self-map of open unit disk $\mathbb{D}$. The operator given by $(C_\varphi f)(z) = f(\varphi(z))$, for $z \in \mathbb{D}$ and f analytic on $\mathbb{D}$ is called a composition operator. Let ω be a weight function such that $\omega \in L^1(\mathbb{D}, dA)$, where dA denotes the normalized area measure on $\mathbb{D}$. The generalized weighted Nevanlinna class $\mathcal{N}_\omega$ consists of all analytic functions f on $\mathbb{D}$ such that $\|f\|_\omega = \int_{\mathbb{D}} \log^+(|f(z)|)\omega(z)dA(z)$ is finite; that is, $\mathcal{N}_\omega$ is the space of all analytic functions belong to $L_{\log^+}(\mathbb{D}, \omega dA)$. In this talk we investigate the boundedness, compactness and the essential norm of these composition operators on the space $\mathcal{N}_\omega$. (Received September 12, 2014)

1106-47-1396 **Michael Y Sun*** (sunm@uni-muenster.de). *Existence of the Matui-Sato tracial Rokhlin property.*

We construct examples of group actions on C*-algebras with the so called tracial Rokhlin property and examine their crossed product C*-algebras from the point of view of the classification program for C*-algebras. (Received September 12, 2014)

1106-47-1417 **Dhruba R. Adhikari***, 1100 S. Marietta Pkwy, Marietta, GA 30060. *Nonzero Solutions to Operator Inclusions Involving Perturbed Maximal Monotone Operators.* Preliminary report.

Let X be a real reflexive Banach space and G_1, G_2 two nonempty, open and bounded subsets of X such that $0 \in G_2$ and $\overline{G_2} \subset G_1$. Let $T : X \supset D(T) \to 2^{X^*}$ be a positively homogeneous maximal monotone operator of degree $\alpha \in (0, 1]$, $C : X \supset D(C) \to X^*$ a bounded demicontinuous of type (S_+), and $G : X \supset D(G) \to 2^{X^*}$ of class (P) as introduced by Hu and Papageorgiou. The problem of existence of nonzero solutions for $Tx + Cx + Gx \ni 0$ is solved by utilizing the Browder and Skrypnik degree theories. This theory generalizes similar results of the author and Kartsatos for $\alpha = 1$ and $G = 0$ and has applications in elliptic and parabolic boundary value problems involving $p-$Laplacian with $p \in (1, 2]$. (Received September 12, 2014)

1106-47-1539 **Gajath Gunatillake*** (mgunatillake@aus.edu), **Mirjana Jovovic** and **Wayne Smith**. *Numerical Ranges of Weighted Composition Operators.*

The operator that takes the function f to $\psi f \circ \varphi$ is a weighted composition operator. We study numerical ranges of some classes of weighted composition operators on H^2, the Hardy-Hilbert space of the unit disc. (Received September 14, 2014)

1106-47-1590 **R. Tully-Doyle*** (ryan.tullydoyle@gmail.com). *Representations of Pick functions in several variables.*

The Pick class in one complex variable is the family of holomorphic functions with non-negative part on the complex upper halfplane. Two classical integral representations, referred to as Nevanlinna representations, characterize functions in the Pick class in terms of positive measures on the real line. I will discuss the generalization of these representations to Pick functions in several variables in terms of self-adjoint operators on a Hilbert space. (Received September 14, 2014)

1106-47-1629 **Christopher P Schafhauser*** (cschafhauser2@math.unl.edu). *AF-Embeddings of Certain Graph C^*-Algebras.*

We discuss the AF-embeddability of graph C^*-algebras. If E is a discrete graph, then for the C^*-algebra $C^*(E)$, the conditions AF-embeddable, quasidiagonal, stably finite, and finite, are equivalent and can be characterized by a simple combinatorial condition on the graph. A similar result holds if either E is a compact topological graph with no sinks or if E is a totally disconnected topological graph. (Received September 14, 2014)

1106-47-1637 **Matthew J. Ziemke***, University of South Carolina, Department of Mathematics, 1523 Greene Street, Columbia, SC 29208, and **George Androulakis**, University of South Carolina, Department of Mathematics, 1523 Greene Street, Columbia, SC 29208. *Generators of Quantum Markov Semigroups.*

Quantum Markov Semigroups (QMSs) originally arose in the study of the evolutions of irreversible open quantum systems. Mathematically, they are a generalization of classical Markov semigroups where the underlying function space is replaced by a non-commutative operator algebra. In the case when the QMS is uniformly continuous, theorems due to Lindblad, Stinespring, and Kraus imply that the generator of the semigroup has the form

$$L(A) = \sum_{n=1}^{\infty} V_n^* A V_n + GA + AG^*$$

where V_n and G are elements of the underlying operator algebra. The form of the generator of a general QMS acting on the bounded operators of a Hilbert space remained open since 1976. In a recent work we proved the generators of general QMSs (not necessarily uniformly continuous) must also satisfy the form given by Lindblad and Stinespring. In this talk I will explain these results and present some examples in order to clarify these findings. (Received September 14, 2014)

1106-47-1654 **Injo Hur*** (ihur@math.ou.edu), Department of Mathematics, University of Oklahoma, Norman, OK 73019-3103. *Classification of Schrödinger operators in terms of a canonical system.*

We classify Schrödinger operators in a canonical system. In particular, we will show that Schrödinger equation will be transformed to a canonical system with a special form. (Received September 14, 2014)

1106-47-1739 **Erin E. M. Rizzie*** (rizziee@purdue.edu). *Some results in the study of multiple-valued composition operators.* Preliminary report.

Given an analytic self-map φ of the complex unit disk, the composition operator C_φ is defined on $H^2(\mathbb{D})$ by the equation $C_\varphi f = f \circ \varphi$. Composition operators on H^2 have been studied extensively since the 1960s. In 1996, C. Cowen and E. Gallardo-Gutierrez extended this concept by defining the *multiple-valued composition operator* C_φ by $C_\varphi f = \sum f \circ \varphi_i$, where the sum is taken over all branches φ_i of a multivalued function φ, as occurs in the case of the inverse of a non-injective function. This definition was conceived by Cowen and Gallardo-Gutierrez when operators of this form appeared as adjoints of composition operators. However, these operators have not yet been studied much further. This talk will discuss some results in the study of multiple-valued composition operators. (Received September 16, 2014)

1106-47-1770 **Victor Vinnikov*** (vinnikov@math.bgu.ac.il), Department of Mathematics, Ben Gurion University of the Negev, Beer Sheva, Israel. *Noncommutative Integrability.* Preliminary report.

Applying the noncommutative difference-differential operator to a noncommutative function yields a new object called a noncommutative function of order 1 (the original function is then a noncommutative function of order

0). I will discuss (necessary and perhaps also sufficient) conditions for a noncommutative function of order 1 to be integrable, i.e., to be the result of applying the noncommutative difference-differential operator to a noncommutative function of order 0. This talk is based on a joint work with Dmitry Kaliuzhnyi-Verbovetskyi. (Received September 15, 2014)

1106-47-1810 **Dan D. Pascali*** (dp39@nyu.edu), 251 Mercer Street, New York, NY 10012-1185. *New operator-numerical advances on Hammerstein equations.*

The Hammerstein operator on a Banach space corresponds to a perturbation of the identity by a product of two operators. More precisely, it has the form with linear component and nonlinear factor where is other Banach space. By chosing different sutable spaces various classes of linear and non-linear mappings were been introduced, to prove that the Hammerstein equation has solutions. We give emphasis to new connections between some existence results, Petryshyn's A-proper solvability and new iterative methods. (Received September 15, 2014)

1106-47-1996 **J. E. Pascoe***, 9500 Gilman Drive # 0112, La Jolla, CA 92093-0112. *Free functions with symmetry.*

In 1936, Margarete C. Wolf showed that the ring of symmetric free polynomials in two or more variables is isomorphic to the ring of free polynomials in infinitely many variables. In some recent work with David Cushing and Ryan Tully-Doyle, we showed that there is an isomorphism from an arbitrary ring of invariants, of which symmetric functions are a special case, to the ring of free polynomials in some number of variables which extends to the free functional calculus as a norm-preserving isomorphism of function spaces on a domain known as the row ball. Furthermore, to construct this isomorphism, we developed a rudimentary theory of bases for the ring of invariants that are compatible with free analysis on the row ball. In this talk, we will discuss several special cases of the above result in detail: 1. Even functions in two variables (that is, functions which satisfy $f(X,Y) = f(-X,-Y)$,) 2. Cyclically symmetric functions in three variables (functions satisfying $f(X,Y,Z) = f(Y,Z,X)$,) 3. Symmetric functions in two variables (functions satisfying $f(X,Y) = f(Y,X)$.) (Received September 15, 2014)

1106-47-2116 **Brittney R. Miller*** (mille753@purdue.edu). *Kernels of Composition Operators and Their Adjoints on the Bergman Space.* Preliminary report.

Let φ be an analytic function from $\mathbb{D}$ to itself. Then, the composition operator C_φ, with symbol φ, is defined by $C_\varphi f = f \circ \varphi$ for f in a Hilbert space of analytic functions on $\mathbb{D}$. Results in the Hardy space relate the kernels and spectra of this composition operator and its adjoint to properties of φ. In this talk, I will discuss similar results in the Bergman space for the class of functions φ where $\varphi(0) = 0 = \varphi'(0)$. (Received September 15, 2014)

1106-47-2598 **William Benjamin Grilliette*** (w.b.grilliette@gmail.com). *Examples of Scaled-free Operator Spaces.* Preliminary report.

This talk continues the study of array-weighted sets and scaled-free matrix-normed spaces. Here, I demonstrate particular examples of the construction of a scaled-free matrix-normed space, showing the effect of the array-weight on the algebraic structure. (Received September 16, 2014)

1106-47-2637 **Daniel J Hoff*** (d1hoff@ucsd.edu). *Von Neumann Algebras of Equivalence Relations with Nontrivial One-Cohomology.*

A natural question in the classification of von Neumann algebras asks which type II_1 factors are prime, i.e. which II_1 factors cannot be written as the tensor product of two diffuse von Neumann subalgebras. Peterson showed that the group von Neumann algebra $L(\Gamma)$ is prime for any countable group Γ which admits an unbounded 1-cocycle into the left regular representation. In this talk, we focus on the case of the von Neumann algebra $L(\mathcal{R})$ for a countable ergodic pmp equivalence relation $\mathcal{R}$ and give an analogous result in this case: $L(\mathcal{R})$ is prime for any nonamenable $\mathcal{R}$ which admits an unbounded 1-cocycle into a mixing orthogonal representation weakly contained in the regular representation. We outline a proof based on Popa's powerful deformation/rigidity theory. (Received September 16, 2014)

1106-47-2723 **Scott M. LaLonde*** (slalonde@uttyler.edu), Department of Mathematics, University of Texas at Tyler, 3900 University Boulevard, Tyler, TX 75799. *Equivalence and Exact Groupoids.* Preliminary report.

An interesting equivalence relation for locally compact Hausdorff groupoids arises when two groupoids admit suitably nice actions on the same space. This notion of groupoid equivalence is strictly weaker than isomorphism, but it is strong enough to preserve certain desirable properties. These ideas are strongly paralleled by those surrounding the theory of Morita equivalence for C^*-algebras. Indeed, equivalence of groupoids is intimately connected to the Morita equivalence of the associated groupoid C^*-algebras. Given this connection, I will describe how the proof of a purely C^*-algebraic result can be mimicked to show that a property called exactness is preserved under groupoid equivalence. Along the way, I will discuss groupoid crossed product C^*-algebras and some classical ideas that motivate the study of groupoid equivalence. (Received September 16, 2014)

1106-47-2863 **M. Zuhair Nashed*** (`zuhair.nashed@ucf.edu`), Department of Mathematics, University of Central Florida, Orlando, FL 32816-1346. *Applications of Hermitian Ordering and Spectral Theory to Operator and Matrix Inequalities.* Preliminary report.

We illustrate the use of Hermitian ordering and spectral theory of bounded linear operators in the derivation of operator inequalities, Kantorovich-type inequalities, and extremal characterizations of generalized inverses of operators. (Received September 16, 2014)

1106-47-2934 **Pando G. Georgiev*** (`pando.georgiev@ucf.edu`), Department of Mathematics, University of Central Florida, Orlando, FL 32816-1364. *Reproducing Kernel Banach Spaces and their Applications to Classification, Clustering and Big Data Problems.*

We present a generalization of the Lax-Milgram theorem and use it for defining a new class of Reproducing Kernel Banach Spaces. The substantial idea in the definition is to use also surjectivity-type theorems. Several applications are presented to: classification problems (a generalization of the support vector machine classifier, sparse proximal support vector machines), subspace clustering, and big data problems. A particular case of subspace clustering leads to signal separation problems based on sparsity assumptions of the source signals. Similarly, subspace clustering leads to sparse approximate representation of multivariate signals. Applications to non-linear dimensionality reduction, non-linear skeletons of data sets and non-linear signal separation are presented. (Received September 17, 2014)

49 ► *Calculus of variations and optimal control; optimization*

1106-49-30 **Richard A. Tapia*** (`rat@rice.edu`), Department of CAAM-MS 134, Rice University, 6100 Main St., Houston, TX 77005. *The Remarkable Journey of the Isoperimetric Problem: From Euler to Steiner to Weierstrass.*

In this presentation we give an overview of the remarkable life of the impactful isoperimetric problem. We identify three distinct classes of solution approaches that have been used throughout history; the Cartesian coordinate representation approach of Euler, the synthetic geometry approach of Steiner, and the parametric representation approach of Weierstrass. We say that one of our three classes of approaches has been completed when an appropriately short sufficiency proof has been constructed that belongs to this class. In 1744 in a legendary work Euler presented his contribution. Euler incorrectly believed that he had established sufficiency; when in reality he had not even established the necessity that he has been credited with by mathematical historians. This failure led Steiner in 1838 to propose his approach which gave only necessity and not sufficiency as he believed. The Steiner path was completed by Lawlor in 1998. Euler's and Steiner's failures led Weierstrass in 1879 to propose his approach, which did indeed lead to sufficiency but was excessively long. The Weierstrass approach was completed in 1934 by Littlewood, Hardy, and Polya. The major contribution in this presentation is the completion of Euler's approach. Our proof is surprisingly elementary. (Received September 03, 2014)

1106-49-103 **Boris S. Mordukhovich** (`boris@math.wayne.edu`), Detroit, MI 48202, and **Wei Ouyang*** (`wei@wayne.edu`), Detroit, MI 48202. *Higher-order metric subregularity and its applications.*

This paper is devoted to the study of metric subregularity and strong subregularity of any positive order q for set-valued mappings in finite and infinite dimensions. While these notions have been studied and applied earlier for $q = 1$ and—to a much lesser extent—for $q \in (0, 1)$, no results are available for the case $q > 1$. We derive characterizations of these notions for subgradient mappings, develop their sensitivity analysis under small perturbations, and provide applications to the convergence rate of Newton-type methods for solving generalized equations. (Received July 16, 2014)

1106-49-222 **Aaron Carl Smith*** (aaron.smith@ucf.edu), Department of Mathematics, University of Central Florida, 4393 Andromeda Loop N, Orlando, FL 32816-1364. *Looking for an Optimal Unistochastic Preimage.* Preliminary report.

A natural map sends unitary matrices to a subset of bistochastic matrices. We refer to matrices in the image of the map as being unistochastic. During the talk the map will be defined, properties will be discussed, and an algorithm for finding unitary matrices in a given unistochastic matrix's preimage will be presented. The goal of the algorithm is to find arguments that minimize the difference between the identity matrix and the product of a matrix with its adjoint. The algorithm uses proximal unitary matrices to simultaneously find all arguments of a matrix in the preimage. (Received August 12, 2014)

1106-49-237 **Abebaw Tadesse***, atadesse@langston.edu, and **Andrew Bucki**. *Radiation therapy planning as an inverse problem – Mathematical perspective.* Preliminary report.

In this talk, we will discuss recent developments of radiation therapy planning from a mathematical perspective. Particular emphasis is given on the two fundamental approaches: Continuous analytic inversion and fully-discretized algebraic methods. Some 2D artificial geometries and anonymized imaging data available at the CERR (Computational Environment for Radiation Therapy Research) archive will be used to demonstrate recent developments on algebraic/numerical techniques. (Received August 13, 2014)

1106-49-324 **Alexander J Zaslavski*** (ajzasl@tx.technion.ac.il), Haifa, Israel. *Dynamic string-averaging projection methods for convex feasibility problems in the presence of computational errors.*

We study convergence of dynamic string-averaging projection methods for solving convex feasibility problems in a Hilbert space. Our goal is to obtain an approximate solution of the problem in the presence of computational errors. (Received August 22, 2014)

1106-49-345 **THANYARAT JITPEERA*** (t.jitpeera@hotmail.com), RAJAMANGALA UNIVERSITY OF TECHNOLOGY LANNA, PHAN, CHIANGRAI 57120, Thailand, and **POOM KUMAM** (pukka6111@hotmail.com), KMUTT, BANGMOD, BANGKOK 14140, Thailand. *Fixed point optimization algorithm and its application to network resource.* Preliminary report.

The variational inequality problem for an inverse strongly monotone over the fixed point set of a nonexpansive mapping includes signal processing problems and network resource allocation problems. We devised an iterative algorithm for solving triple hierarchical problem. The strong convergence for the proposed algorithm to the solution is guaranteed under some assumptions. Our results extend ones of Iiduka(2009), Iiduka (2012) and study ones of Ceng et.al(2011) , Yao et.al(2011) some authors. Moreover, we apply the proposed algorithm to a network bandwidth allocation problem and show its effectiveness. (Received August 24, 2014)

1106-49-738 **Luis A Melara*** (lamelara@ship.edu), 1871 Old Main Drive, Shippensburg, PA 17257-2299, and **Edray Goins**, **Alejandra Alvarado**, **Karoline Pershell**, **Emille Lawrence** and **Naiomi Cameron**. *Numerical Approximation of Coefficients of Belyĭ Maps.* Preliminary report.

In 1984, Alexander Grothendieck, inspired by a result of Gennadiĭ Belyĭ from 1979, constructed a finite, connected planar bipartite graph via rational functions $\beta : \mathbb{P}^1(\mathbb{C}) \to \mathbb{P}^1(\mathbb{C})$ with critical values $\{0, 1, \infty\}$ by looking at the inverse image of the triangle formed by these three points. He called such graphs Dessins d'Enfants. Conversely, Riemann's Existence Theorem implies that every finite, connected planar graph arises in this way.

The difficulty arises in explicitly constructing such a Belyĭ map β from any given planar graph. We may form a valency list by considering the number of edges surrounding each vertex and each face; this forces algebraic conditions on the coefficients of the desired Belyĭ map. Hence the construction of a Belyĭ map can be reduced to the computation of roots of a system of nonlinear equations. In this talk, we reformulate the problem of finding these roots into an unconstrained optimization problem. We implement Newton's method and a Trust-Region Method to approximate these coefficients. Preliminary results are presented and possible directions are discussed. (Received September 05, 2014)

1106-49-752 **Mohsen Razzaghi*** (razzaghi@math.msstate.edu). *Polynomial series direct method for problems in the calculus of variations.*

Orthogonal functions and polynomial series, often used to represent an arbitrary time function, have been used in the last several years to solve various problems of dynamical systems. The main characteristic of this technique is that it reduces these problems to those of solving a system of algebraic equations; thus greatly simplifying the problem. The approach is based on converting the underlying differential equations into an integral equation through integration, approximating various signals involved in the equation by truncated orthogonal functions or polynomial series and using the operational matrix of integration, to eliminate the integral operations. The direct methods of Ritz and Galerkin in solving variational problems are well known. In this talk the Taylor series expansion is first used to solve a calculus of variation problem. It will be seen that to obtain the Taylor series coefficients we need to use an ill-conditioned matrix and hence the Taylor series are not suitable for the solution of a class of calculus of variations problems. Alternative approaches with satisfactory results are given. (Received September 05, 2014)

1106-49-858 **Asen L Dontchev***, 416 Fourth Street, Ann Arbor, MI 48103. *Dennis–Moré Theorems for Nonsmooth Generalized Equations.* Preliminary report.

Generalizations of the Dennis–Moré theorem will be presented regarding superlinear convergence of inexact semismooth quasi-Newton type methods for solving generalized equations. (Received September 08, 2014)

1106-49-909 **Julia Eaton*** (jreaton@uw.edu), Interdisciplinary Arts & Sciences, Box 358436, 1900 Commerce St., Tacoma, WA 98402, and **Mert Gürbüzbalaban**, **Sara Grundel** and **Michael L Overton**. *Optimal Solutions to a Root Minimization Problem over a Polynomial Family with Affine Constraints.*

Consider the system $y' = A(x)y$, where A is a matrix depending on a parameter $x \in \Omega \subset \mathbb{C}^k$. This system is Hurwitz-stable if the eigenvalues of $A(x)$ lie in the left half of the complex plane and Schur-stable if the eigenvalues of $A(x)$ lie in the unit disk. A related topic is to consider polynomials whose coefficients lie in a parameter set. In 2012, Blondel, Gürbüzbalaban, Megretski and Overton investigate the Schur and Hurwitz stability of monic polynomials whose coefficients lie in an affine hyperplane of dimension $n-1$ in $\mathbb{R}$ and $\mathbb{C}$, respectively. They provide explicit global solutions to the radius minimization problem and closely related results for the abscissa minimization problem for a family of polynomials with one affine constraint. In addition to their theoretical results, the authors provide Matlab implementations of the algorithms they derive. A major question that is left open is: suppose there are $\nu \in \{2, \ldots, n-1\}$ constraints on the coefficients, not just one. Our current work is to extend results on the polynomial radius and abscissa minimization problems to this more general case. (Received September 08, 2014)

1106-49-968 **Robert J Kipka*** (kipka@mast.queensu.ca) and **Yuri S. Ledyaev**. *Pontryagin Maximum Principle for Control Systems on Infinite Dimensional Manifolds.*

We discuss a mathematical framework for the analysis of optimal control problems on infinite-dimensional manifolds which can arise in the study of certain partial differential equations. We present techniques of nonsmooth analysis and Lagrangian charts and illustrate their use for the study of global variations of trajectories and derivation of the Pontryagin Maximum Principle for infinite-dimensional problems. (Received September 09, 2014)

1106-49-1329 **Miguel Sama*** (msama@ind.uned.es), Calle Juan del Rosal, 12 ETSI Industriales, UNED, 28040 Madrid, Madrid, Spain, and **Akhtar Khan**. *Regularization error estimates for integral constraint regularization of state-constrained elliptic control problems.*

In this talk we deal with state-contrained elliptic control problem, in particular we deal with integral regularization methods (Systems & Control Letters 61 (2012) 707-713). We give several estimates for the regularization error and we present some new results on the regularity and convergence of the regularized controls and associated Lagrange multipliers. Finally we show how we can apply these results in order to get numerical error estimates for a discretization of the original problem. (Received September 12, 2014)

1106-49-1400 **Mau Nam Nguyen*** (mnn3@pdx.edu), Department of Mathematics and Statistics, 725 SW Harrison Street, Portland, OR 97201. *A D.C. Algorithm via Convex Analysis Approach for Solving a Location Problem Involving Sets.*

We study a location problem that involves a weighted sum of distances to closed convex sets. As several of the weights might be negative, traditional solution methods of convex optimization are not applicable. After obtaining some existence theorems, we introduce a simple effective algorithm for solving the problem. Our method is based on the Pham Dinh - Le Thi algorithm for d.c. programming and a generalized version of the Weiszfeld algorithm. (Received September 12, 2014)

1106-49-1424 **Behzad Djafari Rouhani*** (behzad@utep.edu), Department of Mathematical Sciences, University of Texas at El Paso, 500 W. University Ave., El Paso, TX 79968, and **Kaleem Raza Kazmi** and **Mohammad Farid**. *Iterative Methods for Generalized Mixed Equilibrium and Fixed Point Problems for Nonexpansive Semigroups in a Hilbert Space.*

We introduce an explicit hybrid relaxed extragradient iterative method to approximate a common solution to a generalized mixed equilibrium problem and fixed point problem for a nonexpansive semigroup in a Hilbert space. Then we prove that the sequence generated by the proposed iterative scheme converges strongly to the common solution of the generalized mixed equilibrium problem and fixed point problem for the nonexpansive semigroup. This common solution is the unique solution of a variational inequality problem, and is the optimality condition for a minimization problem. Our results improve and generalize upon the previously known results in this area. (Received September 12, 2014)

1106-49-1500 **Boris Mordukhovich** and **Ebrahim Sarabi***, Wayne State University, Department of Mathematics, 656 W Kirby Rm 1150 Admin Bldg, detroit, MI 48202. *Second-order of piecewise linear functions and its applications.*

This talk is devoted to present second-order analysis of generalized derivative for piecewise linear functions. We provide a complete local analysis by using appropriate generalized differentiation for this remarkable class of functions. Some applications to stability analysis were discussed at the end. (Received September 13, 2014)

1106-49-1587 **Akhtar A. Khan***, Center for Applied and Comp. Math., School of Mathematical Sciences, Rochester Institute of Technology, Rochester, NY 14623. *A Continuous Heavy Ball Method for Elliptic Inverse Problems.* Preliminary report.

This talk will focus on the inverse problem of identifying variable parameters in partial differential equations by developing a continuous as well as discrete heavy ball with friction method. (Received September 14, 2014)

1106-49-1588 **Peter Caya***, Center for Applied and Comp. Math., School of Mathematical Sciences, Rochester Institute of Technology, Rochester, and **Baasansuren Jadamba** and **Akhtar A. Khan**. *Numerical Identification of a Parameter in Fourth-Order Partial Differential Equations by a Modified Output Least Squares.* Preliminary report.

This talk will focus on the inverse problem of identifying parameters in a fourth-order boundary value problem by using a modified output least squares. Numerical results will be presented. (Received September 14, 2014)

1106-49-1591 **Baasansuren Jadamba** and **Raphael Kahler***, Center for Applied and Comp. Math., School of Mathematical Sciences, Rochester Institute of Technology, Rochester, NY 14623, and **Akhtar A Khan**. *Continuous Methods for the Inverse Problem of Identifying a Parameter in Fourth-Order Boundary Value Problems.* Preliminary report.

This talk will focus on the feasibility of differential equations based solvers for solving the inverse problem of identifying variable parameters in fourth-order boundary value problems. We will discuss the use of differential equation solvers such as Euler Method, Trapezoidal Method, Runge-Kutta Methods and Adams-Bashforth Method. The performance and accuracy of these methods to solve the inverse problem will be discussed. (Received September 14, 2014)

1106-49-1648 **Baasansuren Jadamba*** (bxjsma@rit.edu), School of Mathematical Sciences, Rochester Institute of Technology, 85 Long Memorial Drive, Rochester, NY 14623. *Stability of an equation error approach for an inverse problem.*

Equation error approach for an inverse problem arising from identification of a tumor in human body is discussed. Inverse problem is considered in an optimization framework and we use H_1 regularization in the formulation. Joint work with M.S.Gockenbach, A.A.Khan, Ch.Tammer, and B.Winkler. (Received September 14, 2014)

1106-49-1732 **Bao Truong*** (btruong@nmu.edu), Department of Mathematics, Northern Michigan University, Marquette. *Fixed points and variational principles with applications to behavioral sciences.*

In this talk, we present a unified dynamical approach to variational principles and fixed point theorems involving set-valued mappings acting from quasimetric spaces into topological spaces with variable ordering structures. Besides the mathematical novelty, our motivation comes from applications to adaptive dynamical models of behavioral sciences. (Received September 15, 2014)

1106-49-1859 **Christiane Tammer*** (christiane.tammer@mathematik.uni-halle.de), Institute of Mathematics, 06099 Halle, Germany, and **Kathrin Klamroth**, **Elisabeth Köbis** and **Anita Schöbel**. *A unified approach to uncertain optimization.*

Most optimization problems involve uncertain data due to measurement errors, unknown future developments and modeling approximations. For companies, these uncertainties could be future demands that have to be predicted in order to adapt the production process. In risk theory, assets are naturally affected by uncertainty due to market changes, changing preferences of customers and unforeseeable events. Consequently, it is highly important to introduce uncertain parameters to optimization problems.

Two approaches regarding uncertain optimization problems have been concentrated on in the literature. First, stochastic optimization assumes that the uncertain parameter is probabilistic. The second approach is called robust optimization, which expects the uncertain parameter to belong to a set that is known prior to solving the optimization problem. The focus lies on looking at the worst case, hence no probability distribution is needed.

Our goal is to present unifying concepts for both stochastic and robust optimization also for the case of infinite uncertainty sets. In particular we show that robust and stochastic optimization problems can be expressed by a vector optimization approach, by a set-based approach and by using nonlinear scalarizing functionals. (Received September 15, 2014)

1106-49-1890 **Abhishek Mallela*** (am9d5@mail.umkc.edu), 508 NW O'Brien Road, Lee's Summit, MO 64063, and **Suzanne M Lenhart** and **Naveen K Vaidya**. *Optimal Treatment Strategies for HIV-TB Co-Infected populations.*

There exists an important question (and hot debate) of whether the initiation of ART (Antiretroviral Therapy) during ongoing TB treatment is appropriate or not. If ART is administered early in the presence of TB treatment, the advantages are that there will be fewer deaths due to AIDS and less risk of transmission due to HIV. The disadvantages, though, are significant complications, including IRIS and a high pill burden. If ART is administered late in the presence of TB treatment, the opposite outcomes are obtained. In this talk, I will present a mathematical model, which helps us identify an optimal ART treatment strategy for co-infected people undergoing TB treatment. Using our model, we further develop an optimal control problem in order to achieve a minimum burden (sum of new IRIS cases, IRIS deaths, new HIV infections, and AIDS deaths) from this co-infection.

(Received September 15, 2014)

1106-49-1913 **Wyatt Boyer*** (wbb1@williams.edu), **Bryan Brown** (bcb02011@mymail.pomona.edu), **Alyssa Loving** (aloving@hawaii.edu) and **Sarah Tammen** (setammen@uga.edu). *Constrained Optimal Transportation.*

Optimal transportation seeks the least-energy way to transport material (like a pile of sand) from initial sites to destinations. McCann et al. have recently considered a constraint on the flow from x to y. We provide some new examples and results. (Received September 15, 2014)

1106-49-2197 **Ugur G. Abdulla*** (abdulla@fit.edu), 150 West University Blvd, Melbourne, FL 32901. *Inverse Free Boundary Problems for the Parabolic PDEs.*

We present a new variational formulation of the inverse Stefan problem, where some of the coefficients of the PDE or some boundary data on the fixed boundary is missing and must be found along with the temperature and free boundary. Optimal control framework is employed where missing data and free boundary are the components of the control vector and optimality criteria consists of the minimization of L_2-norm declinations from the available measurement of the temperature and available information on the phase transition temperature on the free boundary. In a recent paper *U.G. Abdulla, Inverse Problems and Imaging, 7,2(2013),307-340* well-posedness in Sobolev spaces framework and convergence of the method of lines is proved. In this work we introduce full space-time discretization and prove the convergence of discrete optimal control problems to the original problem both with respect to cost functional and control. We also prove Frechet differentiability, Pontryagin type maximum principle and implement iterative gradient method in Hilbert spaces. (Received September 16, 2014)

1106-49-2218 **Sijie Liu*** (sliu28@crimson.ua.edu), University of Alabama, Department of Mathematics, Gordon Palmer Hall, Box 870350, Tuscaloosa, AL 35487, and **Min Sun**, University of Alabama, Department of Mathematics, Gordon Palmer Hall, Box 870350, Tuscaloosa, AL 35401. *New Sampling Strategy for Solving Linear Equality Constrained Optimization Problems.* Preliminary report.

A novel interval-based algorithm is proposed for solving global optimization problem with continuous objective function subject to the linear equality constraints over any bounded interval domain. The algorithm uses new sampling procedures by applying Affine Arithmetic and an adaptive Steepest Descent framework, combined with a hybrid step-size estimation. The introduced sampling technique results in improved performance for testing the feasibility in any subdomains and locating a feasible point if the subdomain is nonempty when compared to the basic interval algorithm which only using midpoint sampling strategy. New algorithm has been implemented in C and the numerical results presented demonstrates the robustness and efficiency of the procedures. (Received September 16, 2014)

1106-49-2699 **R. R. Poteau*** (rpoteau2010@my.fit.edu) and **U. G. Abdulla**. *Identification of parameters in mathematical biology.*

We consider inverse problems for the identification of parameters for systems of nonlinear ODEs arising in mathematical biology. We implement a numerical method suggested in *U.G.Abdulla, Journal of Optimization Theory and Applications, 85, 3(1995), 509-526*. The idea of the method is based on the combination of Bellman's quasilinearization with sensitivity analysis and Tikhonov's regularization. We apply the method to various biological models such as Lotka-Volterra system, the Pielou extension, bistable switch model in genetic regulatory networks, an angiogenesis model, a three-step pathway modelled by 8 nonlinear ordinary differential equations, etc. Numerical results confirm the quadratic convergence. Some challenges associated with the size of the system and unknown parameters, as well as the length of the time interval are discussed. (Received September 16, 2014)

51 ► Geometry

1106-51-287 **Isabel Corona**, **Carolynn Johnson**, **Lon Mitchell** and **Dylan O'Connell*** (doconnel@haverford.edu), 161 Waban Hill Road North, Newton, MA 02467. *A New Look at Apollonian Circle Packings.* Preliminary report.

Apollonian gaskets are circle packings that are the subject of significant current research. We first extend previous results about Ford circles to the Apollonian gasket that contains them. We then create a new labeling that provides a variety of advantages when examining the gasket and use the properties of this labeling to describe a more general circle arrangement, termed a "super-packing". We consider the sets of curvatures that can occur within our arrangement and discuss the relationship between circle inversion and our construction. We then generalize our results to the case of an Apollonian sphere packing. This research was conducted at the REU program at Central Michigan University. (Received August 19, 2014)

1106-51-1168 **Andrea N Young*** (younga@ripon.edu). *A Discrete Yamabe Problem.* Preliminary report.

The Yamabe problem in smooth differential geometry asks whether a given metric on a smooth, compact manifold M^n, $n \geq 3$, is conformal to one having constant scalar curvature. This talk will focus on a related question in the setting of triangulated, piecewise-flat manifolds. Known results will be presented. A preliminary report of work done under the auspices of a grant from the Center for Undergraduate Research in Mathematics will also be given. (Received September 11, 2014)

1106-51-1253 **Kusha Mohammadi** and **J Mealy*** (jmealy@austincollege.edu), Austin College, suite 61560, 900 North Grand Avenue, Sherman, TX 75090. *Piecewise domains in staircase metric space-times.*

Further results in the category, staircase metric geometry. After an introduction to and overview of this new general category of geometric systems, and of its associated natural methodology, we focus on the most recent extension of the category. Both in the positive definite and signature cases, (2,0) and (1,1), we consider parameter spaces that, while topologically path connected, are comprised of unions (possibly countably infinite) of specific non-convex subsets of planes, with each featuring a different 'scale factor' (or, 'index of refraction'); the connection scheme for these subsets is straightforward. New angle change laws for geodesics are derived (governing the transitions across the parameter space pieces) in both cases. Then, a variety of complete geodesics are constructed and exhibited, notably time-like in the signature case. These can be used further to construct, in some specific systems, asymptotic polygons. Finally, we include a brief discussion of the breadth of the category, staircase metric geometry. (Received September 11, 2014)

1106-51-1275 **Yiqing Cai*** (yiqingcai@ima.umn.edu), 207 Church Street SE, 306 Lind Hall, Minneapolis, 55455, and **Andrew Beveridge**. *Capturing the evader in 2-d Euclidean space with topological strategy.*

Pursuit evasion game in 2-d Euclidean space with smooth boundary and obstacles is discussed in this paper. Both the pursuers and the evader has full visibility of the environment. Suppose they move alternatively with the same maximum speed, and the pursuers would need to physically capture the evader in order to win the game. We prove that three pursuers suffice to win the game, by using a topological strategy to simplify (or to reduce the genus of) the contaminated region. (Received September 11, 2014)

1106-51-1303 **Alyssa Kealohi Loving*** (aloving@hawaii.edu). *Double Bubbles in Hyperbolic Surfaces.*
We seek the least-perimeter way to enclose and separate two prescribed areas in certain hyperbolic surfaces. (Received September 12, 2014)

1106-51-1382 **James J. Madden*** (jamesjmadden@gmail.com), 222 Prescott Hall, Baton Rouge, LA 70803-4918. *Geometry By and For High-School Geometry Teachers.*
The geometry course that is offered for future and practicing high-school teachers at Louisiana State University has been evolving for over two decades. Early on, after experimenting with many texts, we found that students reacted very favorably to Euclid's *Elements*, especially Books I, V and VI, and became more actively engaged in studying this work than any of the numerous alternatives we tried. Many graduates have reported, after several years as geometry teachers, that studying Euclid was memorable, useful and influential in their work in a positive way. The latest version of the course is strongly influenced by the Common Core Standards and devotes significant attention to transformations, but Euclid (in the original) still serves as a foundation. Students in the course have contributed actively and extensively to the design and development of the EngageNY/Eureka-Math geometry curriculum. The college course looks "under the hood" of the high-school course, revealing the deep ideas that give high-school geometry its structure, coherence, usefulness and beauty. In this talk, I will provide a conceptual outline of the course and display and distribute several typical assignments. I will also respond to the objections to Euclid that are occasionally made. (Received September 12, 2014)

1106-51-1441 **Sarah E Tammen*** (setammen@uga.edu). *The Isoperimetric Problem in $\mathbb{R}^n$ with Density r^p.* Preliminary report.
The isoperimetric problem with a density or weighting seeks to enclose prescribed weighted volume with minimum weighted perimeter. According to Gregory Chambers' recent proof of the Log-Convex Density Conjecture, for a certain class of density functions on $\mathbb{R}^n$, isoperimetric regions are balls centered at the origin. We use similar methods of analyzing planar curves to investigate another conjecture that if $\mathbb{R}^n$ has density r^p, where r is distance from the origin and $p > 0$, then isoperimetric regions are bounded by spheres that pass through the origin. This research is a joint project conducted by the Geometry group in the 2014 Williams College "SMALL" program and Gregory Chambers. (Received September 13, 2014)

1106-51-1496 **Derege H Mussa*** (derege.mussa@utdallas.edu), 800 West Campbell Road, Richardson, TX 75080-, Dallas, TX 75080. *Partitions of Tetrahedra.* Preliminary report.
A tetrahedron (Plural : tetrahedra) is a three dimensional solid having four vertices, four triangular faces and six edges which don't lie in a single plane. The labeling of the vertices and edges of this has been chosen to be in accord with the labeling used by J. Scott in describing a very elegant determinant that can be used for telling if there truly exists a tetrahedron with 6 given edge lengths due to W.H. McCrea in the relative positions A sextuple S = (a, b, c, d, e, f) is a tetrahedron if and only if S is facial (the lengths of the edges of each four face must obey the (strict) triangle inequality) and that the McCrean determinant is positive. We classify the tetrahedron according to the edges since the tetrahedron has 6 edges then there are 11 partitions. One can also consider the partition for a particular tetrahedr based on congruence of triangles. Theorem (Derege Mussa Partition) There are 25 different partition classes of tetrahedra taking in to account graph theoretical aspects of the position of the edges, and all 25 types exist. The paper discuss how to determine the existence of tetrahedra , congruence property of tetrahedra in terms their face and vertex partition, and face partition and edges length. (Received September 13, 2014)

1106-51-1512 **Michael Knopf*** (mknopf@berkeley.edu), **Jesse Milzman** (jmm398@georgetown.edu), **Derek Smith** (smithder@lafayette.edu), **Dantong Zhu** (zhud@lafayette.edu) and **Dara Zirlin** (zirli22d@mtholyoke.edu). *Lattice Embeddings of Planar Point Sets.*
In the Euclidean plane, let S be a set of points whose pairwise distances are integers. If the area of each triangle with vertices in S is also an integer, it is not hard to find a congruent copy of S that embeds in $\mathbb{Q}^2$. It is more surprising that S also embeds in $\mathbb{Z}^2$, a result due to Fricke. Fricke's method relies on the unique factorization of the Gaussian integers $\mathbb{Z}[\sqrt{-1}]$.

If the area of some triangle in S is not an integer, by Heron's formula it will be of the form $q\sqrt{d}$, where $d \in \mathbb{Z}$ is square-free and $q \in \mathbb{Q}$. In fact, the area of every triangle in S will be of this form for the same value of d, called the "characteristic" of S. It is then natural to ask whether S embeds in $\mathbb{Z}[\sqrt{-d}]$. The equilateral triangle with side length 1 provides a counterexample for $d = 3$; but the triangle does embed in the maximal order $\mathbb{Z}[\omega]$ of Eisenstein integers, where $\omega = (1 + \sqrt{-3})/2$.

Our main result determines the values of d for which all S with characteristic d embed in the maximal order of the quadratic field $\mathbb{Q}(\sqrt{-d})$. We also provide similar results for point sets whose pairwise distances need only be square roots of integers. (Received September 13, 2014)

1106-51-1536 **Oscar Vega*** (ovega@csufresno.edu), 5245 North Backer Avenue M/S PB 108, Fresno, CA 93740-8001. *α-flokki.* Preliminary report.

α-flokki generalize the well-studied, and well-known, flocks of quadratic cones. They were introduced by Kantor and Penttila, and later on studied by Cherowitzo and Johnson, among others.

Many important results on the theory of flocks of quadratic cones can be extended to α-flokki. In this talk we will present a few of these generalizations. In particular, we will discuss the connections between α-flokki and certain translation planes, and the structure of the collineation group of such planes. (Received September 14, 2014)

1106-51-1790 **Jordan Watts*** (jawatts@illinois.edu), Department of Mathematics, 1409 W Green Street, Urbana, IL 61801. *Calculus on a Symplectic Reduced Space.*

Given a Hamiltonian group action on a symplectic manifold, one can apply symplectic reduction in order to reduce the number of degrees of freedom. However, the result may not be a manifold; in general, it is a symplectic stratified space, and on this space one typically wants to perform differential topology.

We will review a de Rham complex defined by Sjamaar which yields the major theorems of Stokes and de Rham. However, this definition is not intrinsic, and this causes issues when, say, attempting reduction in stages. Is Sjamaar's complex isomorphic to a complex intrinsic to the stratified space?

We then turn our attention to diffeological spaces, and show that in the case of Poisson reduction we obtain a de Rham complex on the orbit space which matches basic forms on the original manifold. We then return to the question above and give a partial affirmative result, and time-permitting we will discuss issues in obtaining the full result.

This is joint work with Yael Karshon. (Received September 15, 2014)

1106-51-1922 **Michael McAsey*** (mcasey@bradley.edu), 1501 W Bradley Ave, Bradley University, Peoria, IL 61625, and **Libin Mou**. *Maximal regular polygons inscribed in a triangle.* Preliminary report.

In analogy with the incircle of a triangle, we consider maximal inscribed regular polygons in a triangle. The radius and center of such an n-gon are found. It is not surprising that as $n \to \infty$, the inscribed polygons tend to the inscribed circle. Following a problem stated (and solved) by Calabi on squares in a triangle and work by Jerrard-Wetzel on equilateral triangles inscribed in a triangle, we consider triangles so that the maximal regular polygon can be inscribed in different ways inside its triangle. Jerrard-Wetzel and Calabi each found unique (non-equilateral) triangles for which the maximal equilateral triangle and square (respectively) can be inscribed in different ways. For regular n-gons with $n > 6$, it turns out that there are increasingly many triangles having different ways to inscribe their maximal polygons. An example of the results is that the number of triangles with regular n-gons inscribed in different ways is bounded below by $\lfloor n/4 \rfloor$. So for n large, such triangles are far from unique. (Received September 15, 2014)

1106-51-2097 **Dane P. Mayhook*** (dmayhook@math.fsu.edu). *The Local Isomorphism Class of the Discrete Hyperbolic Plane.*

Two planar polygonal complexes (i.e. polygonal decompositions of the plane) are said to be locally isomorphic if every finite connected subcomplex of one embeds isomorphically in the other, and vice versa. This talk will present the concept of local isomorphism in the context of a single example—the discrete hyperbolic plane H. I will explore the local isomorphism class (H) of this hyperbolic complex, and demonstrate that (H) is uncountably infinite by providing a constructive description of all of its elements. (Received September 16, 2014)

1106-51-2271 **Surya Thapa Magar*** (suryalg@math.ksu.edu). *Skeleta of algebraic curves and surfaces.* Preliminary report.

Given a smooth algebraic surface Z in $(\mathbb{C}^*)^3$ defined by a polynomial f and any unimodular triangulation of its Newton polytope $\triangle$, we give a tropical geometric construction of a 2-dimensional cell complex S and show that Z is homotopy equivalent to S. (Received September 16, 2014)

1106-51-2304 **Traymon Beavers**, **Michael Caple**, **Ezekiel Mihelcic*** (mihelcer@dukes.jmu.edu) and **Lisha White**. *Geometric Modeling of Hexagonal Joints.*

Functional wooden pliers can be constructed from a rectangular block of wood using ten cuts, with negligible loss of volume. These cuts form a hexagonal joint, with two reflectional symmetries, around which the pliers can open. A two-dimensional model describing the mechanics of the three-dimensional pliers was constructed based on the lengths of the cuts and the angles at which the cuts are placed. This model fully predicts whether or not pliers constructed with an arbitrary set of cuts can open and, if so, how far those pliers will open, based solely on the parametrization of the hexagonal joint by a characteristic length, λ, and an angle, θ. Additionally, techniques from linear algebra and analysis are utilized to determine the set of possible pivot points and to derive a closed form solution for the maximum angle of opening, given an arbitrary pivot point. (Received September 16, 2014)

1106-51-2606 **Robert D. Knight*** (knightr@ohio.edu), 101 University Dr., Chillicothe, OH 45601. *A New Perspective on Laguerre Planes.*

Laguerre geometry originated in work by Edmond Laguerre in the late 1800s. Van der Waerden and Smid generalized this geometry by introducing a basic axiomatic system in 1935. Their system is intuitively connected to the representation of a Laguerre plane as an incidence geometry of "circles" and points in a plane. Much of the research into Laguerre planes since has utilized idiosyncrasies of this representation. This approach has been fruitful, but there is a tendency to neglect studying objects not easily visualized within this representation. For example, Laguerre planes contain at least two types of pencils of circles. A parabolic pencil of circles is a maximal set of mutually tangent circles and an elliptic pencil of circles is the set of all circles through two given points. Structures involving several such pencils of circles appear quite complex. We introduce a new axiom system for Laguerre planes that is logically equivalent to the original. This system is defined using a set of affine planes, the points and lines of these planes, and incidence properties between the planes. Parabolic and elliptic pencils of cycles from the old system become lines, making configurations of these objects easier to study. (Received September 16, 2014)

52 ► Convex and discrete geometry

1106-52-389 **Elizabeth McMahon*** (mcmahone@lafayette.edu), **Jordan Awan**, **Claire Frechette** and **Yumi Li**. *A Substructure of Maximal Caps in $AG(4,3)$.* Preliminary report.

It is possible to partition $AG(4,3)$ into 4 disjoint maximal caps (each of size 20) plus a single point; this structure was found using the visualization provided by the card game SET®. Although all maximal caps in $AG(4,3)$ are affinely equivalent, the action of the affine group is not transitive on pairs of disjoint maximal caps. One consequence of this is that the partitions fall into two equivalence classes under that action. Demicaps, a new substructure of the maximal caps, aid in understanding the geometric structure of one of the two classes. (Received August 26, 2014)

1106-52-424 **Arseniy V. Akopyan** and **Alexey Glazyrin*** (alexey.glazyrin@utb.edu). *On the total perimeter of disjoint convex bodies.*

In 2012, Filip Morić and one of the authors posed a conjecture that for any convex planar body S and for any k disjoint convex bodies S_i inside S, the sum of perimeters of these convex bodies must satisfy $\sum p(S_i) \leq p(S) + 2(k-1)d(S)$ (here by p() and d() we mean perimeters and diameters of corresponding bodies). In 2013, this conjecture was proved by Rom Pinchasi.

Using the initial averaging idea of Pinchasi, we suggest a new approach to the conjecture via generalized distances and generalized perimeters defined with respect to convex bodies, in particular, bodies of constant width. (Received August 27, 2014)

1106-52-521 **Karoly Bezdek*** (bezdek@math.ucalgary.ca), University of Calgary, Department of Mathematics and Statistics, Calgary, Alberta T2N 1N4, Canada, and **Zsolt Langi** (zlangi@math.bme.hu), Budapest University of Technology, Department of Geometry, Budapest, Hungary. *Bounds for outer parallel domains of unit ball packings.*

We give upper bounds for the density of finite unit ball packings within their outer parallel domains and discuss a connection to contact numbers. Also, packings of soft balls are introduced and upper bounds are given for the fraction of space covered by them. (Received September 01, 2014)

1106-52-646 **Frank Sottile*** (sottile@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77840, and **Jonathan D Hauenstein**, Department of Applied and Computational Mathe, University of Notre Dame, Notre Dame, IN 46556.
Numerical computation of Newton polytopes.

The Newton polytope of a polynomial f is a combinatorial approximation to f that also encodes much information about the hypersurface H defined by f. In this talk, I will address the problem of how to recover the Newton polytope (or even f) when H is represented numerically via a witness set, which is a data structure capturing the notion of a generic point of H. This talk will describe witness sets and how such a representation may arise without knowledge of f, explain an algorithm for solving this problem, and perhaps how it was used to find a face of the Lüroth invariant. (Received September 04, 2014)

1106-52-647 **Paxton M Turner*** (pturne7@tigers.lsu.edu), 5130 Highland Road Apt. C, Baton Rouge, LA 70808, and **Yuhuai Wu**, 98 Cambridge Cr, Fredericton, NB E3B4N9, Canada.
Discrete Equidecomposability and Period Collapse. Preliminary report.

We present new results in two topics related to Ehrhart theory: equidecomposability and period collapse. First, we disprove a conjecture posed by both J. Kantor and T. McAllister that Ehrhart equivalence implies equidecomposablility. We do so by producing two Ehrhart-equivalent denominator 5 triangles and then developing an invariant to show that they are not equidecomposable. Surprisingly, there does exist an infinite equidecomposability relation between these two triangles if we delete an edge. Also, we provide necessary and sufficient conditions for equidecomposability in terms of a family of graphs associated to minimal triangulations of a given polygon. In the other direction, we give an explicit formula for the Ehrhart quasi-polynomial in terms of the interior and boundary points up to certain dilates of a polygon. Next, we observe a general linear recurrence relation for the coefficients of the Ehrhart series and give a geometric interpretation for this relation. Under some assumptions, we can do this geometric construction for denominator D triangles with period collapse $k|D$, which converts the period collapse problem into studying half-open rational parallelograms whose discrete and continuous areas are the same. We close with some related conjectures and problems. (Received September 04, 2014)

1106-52-684 **Braxton Carrigan***, carriganb1@southernct.edu. *Extendability of Surface Triangulations.* Preliminary report.

A review of literature reveals a common theme for finding non-triangulable polyhedra. The process generally begins with a well-known convex polyhedron and then moves the vertices within an ϵ- neighborhood so that diagonals of the faces of the original polyhedron become concave dihedral edges of the newly created polyhedron. This process is reliant on first knowing that there exists no triangulation of the original polyhedron which uses the diagonals that will become concave dihedral angles. Assuming we have a triangulation of each face, known as a surface triangulation, it is then natural to ask if there exists a partition of the polyhedron into tetrahedra which uses all of the diagonals of the surface triangulation. We will explore the techniques in deciding weather a surface triangulation is extendable to either a triangulation or tiling of the polyhedron and in doing so classify surface triangulations of polyhedra containing only regular faces by their extendability hence creating a larger set of non-triangulable polyhedra. (Received September 04, 2014)

1106-52-1038 **Chad Giusti** (cgiusti@seas.upenn.edu), 316 Hayden Hall, University of Pennsylvania, Philadelphia, PA 19102, and **William Kronholm*** (wkronholm@whittier.edu), Department of Mathematics, Whittier College, Whittier, CA 90608. *Constructing Covers for Convex Codes.*

Associated to a collection of subsets $\{U_i\}_{i=1}^n$ of Euclidean space is a combinatorial code $\mathcal{C} \subset 2^{[n]}$. Each codeword $\sigma \in \mathcal{C}$ corresponds to a non-empty intersection of the subsets $\{U(i) \mid i \in \sigma\}$ which lies the complement of the remainder $\{U(j) \mid j \notin \sigma\}$. Such codes arise in neuroscience when one describes the coding properties of neurons by their *receptive fields*, often modeled by convex regions in some Euclidean "stimulus space". In this talk, we provide a partial characterization of convex codes along with a method for constructing convex covers for a broad class of convex codes. (Received September 15, 2014)

1106-52-1114 **Oleg R Musin*** (oleg.musin@utb.edu), Dept. of Mathematics, UTB, One West University Boulevard, Brownsville, TX 78520. *Extreme point configurations on spheres and locally rigid contact graphs.*

Recently, we solved the Tammes problem for N=13 and N=14 by computer enumerating all locally rigid circle packings on the unit sphere. This problem is equivalent to the enumeration of spherical irreducible contact graphs. In this talk we show that by using the list of irreducible graphs can be solve various problems of extreme packings such as the Tammes problem for the sphere and the projective plane, the maximal contacts problem, Danzer's and other problems on irreducible contact graphs. (Received September 10, 2014)

1106-52-1166 **Clifford Taylor***, clifford.taylor@uky.edu, and **Carl Lee**, lee@ms.uky.edu.
Deletion-Induced Triangulations. Preliminary report.

Let k, $d > 0$ be fixed integers and let $\mathcal{Q} \subset \mathbb{R}^d$ be a collection of points which we lift into $\mathbb{R}^{d+1}$. We will assign to each k-subset of the points of $\mathcal{Q}$ a triangulation obtained by deleting the specified k-subset and projecting down the lower hull of the resulting lifting. Next, for each triangulation we form the characteristic vector outline by Gelfand, Kapranov, & Zelevinsky by assigning to each vertex the sum of volumes of all adjacent simplices. We then form a vector for the lifting, which we call the GKZ vector, by summing the characteristic vectors. Lastly, we construct a polytope $\Sigma_k(\mathcal{Q}) \subset \mathbb{R}^{|\mathcal{Q}|}$ by taking the convex hull of all obtainable GKZ vectors by liftings of $\mathcal{Q}$. In this talk, we discuss the case where $k = d = 1$ and will describe a combinatorial interpretation of the vertices which will allow us to describe and enumerate the vertices and edges of these polytopes for arbitrary sizes of $\mathcal{Q}$. (Received September 11, 2014)

1106-52-1334 **A. Montejano**, **L. Montejano*** (`luis@matem.unam.mx`), **E. Roldán-Pensado** and **P. Soberón**. *About an Erdős-Grünbaum conjecture concerning piercing of non-bounded convex sets.*

In this paper, we study the number of compact sets needed in an infinite family of convex sets with a local intersection structure to imply a bound on its piercing number, answering a conjecture of Erdös and Grünbaum. Namely, if in an infinite family of convex sets in R^d sets we know that out of every p there are q which are intersecting, we determine if having some compact sets implies a bound on the number of points needed to intersect the whole family. We also study variations of this problem. (Received September 14, 2014)

1106-52-1466 **Luis Montejano*** (`luis@matem.unam.mx`). *The floating body problem and a homological characterisation of convexity.*

I will discuss the solution of Problem 68 concerning several topological characterisations of convexity. I will also discuss Problem 19 (the floating body problem) and the solution of the two dimensional case. (Received September 13, 2014)

1106-52-1506 **Ryan Gallagher*** (`ryan.j.gallagher@uconn.edu`), **Jessie De La Cruz Santos** and **Sarah Hadaidi**. *Polygon Curvature Flow.*

The process of deforming a curve by the curvature vector at each point is known as the curve-shortening flow (CSF). Grayson showed that CSF averages the shape of a curve, causing simple, closed curves to become asymptotically circular. Our research applies the idea of curvature flow to polygons. We give a novel definition for the 'curvature vector' at a vertex of a polygon. Deforming in the direction of this curvature vector yields a flow of polygons, the polygon curvature flow (PCF). We numerically investigate the behavior of this flow and show that it exhibits several of the qualitative properties of CSF. We conjecture that PCF makes polygons asymptotically regular. (Received September 13, 2014)

1106-52-1508 **Egon Schulte*** (`schulte@neu.edu`), Northeastern University, Department of Mathematics, Boston, MA 02115. *Polygonal Complexes and Nets.*

Polygonal complexes in space are discrete polyhedron-like structures with finite or infinite polygons as faces, allowed to be planar, skew, zig-zag, or helical, and with finite graphs as vertex-figures. The edge graphs of periodic polygonal complexes are periodic nets in the sense of crystallography. We discuss classification results for polygonal complexes with distinguished symmetry properties. (Received September 13, 2014)

1106-52-1563 **Jim Lawrence*** (`lawrence@gmu.edu`), Department of Mathematical Sciences, 4400 University Drive, George Mason University, Fairfax, VA 22030-4444. *A Number associated with a Hyperplane Arrangement in R^d or a Graph.*

The complement in R^d of an arrangement of hyperplanes is the union of pairwise disjoint pieces, each of which is an open convex polyhedron. These form the vertices of a graph, with two pieces being adjacent provided that the polyhedra share a $(d-1)$-dimensional border. This graph is bipartite. Upon coloring the pieces Red or Blue in such a way that no two adjacent regions have the same color, we may find the (absolute) difference between the number of red and the number of blue pieces. This number, called the *odd-even invariant* of the arrangement, has interesting properties, some of which will be described in this talk. From a graph with n vertices and m edges, it is possible to obtain an arrangement of m hyperplanes in R^{n-1} (in a standard and well-known way). The number above can be obtained, yielding a graphical invariant, closely related to the number of acyclic orientations of the graph. In the graphical case, the invariant has additional properties, some of which we present. There is an *odd-even chromatic polynomial*, which in a way generalizes the ordinary chromatic polynomial. (Received September 14, 2014)

1106-52-1639 **Kevin G. Hare** (kghare@uwaterloo.ca), Department of Pure Mathematics, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada, and **Michael J. Mossinghoff*** (mimossinghoff@davidson.edu), Department of Mathematics & Computer Science, Davidson College, Davidson, NC 28035-6996. *Sporadic Reinhardt polygons.*

A *Reinhardt polygon* is a convex n-gon that, for n not a power of 2, is optimal in three different geometric optimization problems, for example, it has maximal perimeter relative to its diameter. Some such polygons exhibit a particular periodic structure; others are termed *sporadic*. Prior work has described the periodic case completely, and has shown that sporadic Reinhardt polygons occur precisely when n has the form $n = pqr$, with p and q distinct odd primes and $r \geq 2$. We show that sporadic Reinhardt polygons outnumber the periodic ones for almost all n, and determine that this first occurs at $n = 105$. We also compute a formula for the number of sporadic Reinhardt polygons when $n = 2pq$, with p and q distinct odd primes. (Received September 14, 2014)

1106-52-1676 **Deborah Oliveros*** (dolivero@matem.unam.mx), Instituto de Matematicas, Circuito Exterior C.U., Coyoacan, Mexico, 04510. *About the piercing number of boxes and beyond.* Preliminary report.

Finding the piercing numbers for families of convex sets, in relation with Helly's type theorems or Helly Gallai type theorems has been an interesting problem that has attract the attention of many people and, it is known, that theorems of such type are rear. I this talk, we will present some interesting behaviors' of Fractional Helly's Theorem as well as some new bounds for piercing the families of Boxes and flat boxes. (Received September 15, 2014)

1106-52-1728 **Brian Simanek*** (brian.z.simanek@vanderbilt.edu), Vanderbilt Math Department, 1326 Stevenson Center, Nashville, TN 37240. *Optimal Polarization for Integrable Kernels.*

Polarization problems fall into the general category of optimal point placement on manifolds.

Let f be a lower semi-continuous and non-negative function and $\mathcal{A}$ a compact manifold. Every point a in $\mathcal{A}$ generates a potential on $\mathcal{A}$ given by $f(|\cdot - a|)$. The optimal polarization problem consists of finding finite sets of points in $\mathcal{A}$ so that the minimum of the potential they generate is as large as possible. Our main result shows that if the function f is integrable (in the appropriate sense) and satisfies some other mild assumptions, then we can characterize the asymptotic distribution of optimal polarization configurations as the number of points tends to infinity. (Received September 15, 2014)

1106-52-1932 **David Haws*** (dchaws@gmail.com). *Geometric Approach to Learning Bayesian Networks.*

This talk will cover descriptions of probabilistic conditional independence (CI) models and learning Bayesian networks – a type of graphical model – which have applications in natural language processing, biology (epistasis, gene regulatory networks, protein signaling, systems biology), Markov random processes, probabilistic reasoning, artificial intelligence and more. Given observed data, the goal is to find the CI structure which best explains the data. I will overview graphical approaches to the description of CI structures. Then, I will describe a superior algebraic description of CI structures introduced by Studeny et al. which has many elegant properties, suitable for applications of linear programming methods. The remainder of the talk will be devoted to optimization approaches to learning Bayesian networks. (Received September 15, 2014)

1106-52-2053 **Nina Amenta*** (amenta@cs.ucdavis.edu), Department of Computer Science, Univeristy of California, One Sheilds Ave., Davis, CA 95616. *Computational applications of Helly-type Theorems.*

Helly's theorem states that a finite family F of convex sets in $\mathbb{R}^d$ shares a common point if and only if every $G \subseteq F$ of size $|G| \leq d+1$ shares a common point. Analogous Helly-type theorems might concern other sets F and other properties. In many cases, combinatorial algorithms for linear programming can be used to efficiently determine whether F has the property by testing only some of the small subsets G. We will give a several examples, both old and new. (Received September 15, 2014)

1106-52-2110 **Jeremiah Bartz*** (jbartz@fmarion.edu). *Bounds on Induced Multinets.*

Multinets are certain configurations of lines and points with multiplicity in the complex projective plane $\mathbb{P}^2$. They appear in the study of resonance varieties of complex hyperplane arrangement complements. Very few examples of multinets with non-trivial multiplicities are known. Many such examples can be induced by intersecting the generalization of multinets in $\mathbb{P}^3$ with planes. In this talk, we will discuss bounds on the number of points with non-trivial multiplicities for these induced multinets. (Received September 15, 2014)

1106-52-2160 **Bryan A Curtis*** (bcurti11@msudenver.edu). *Finding The Inverse Of A Doodle.* Preliminary report.

In his paper, *The Mathematics of Doodling* [The American Mathematical Monthly, Vol. 118, No. 2, 2011], Ravi Vakil begins by describing a method for doodling conceived during his childhood. Based on his description, a doodle is the result of drawing a curve tightly around some shape on a piece of paper and then continuing to repeat the process about the previously drawn curve. The resulting doodle is, in some respects, the radius r neighborhood of a planar set X, i.e. the collection of points within a distance r of the set X, denoted $N_r(X)$. Vakil explores the geometry of such objects and extends these ideas to polyhedra and beyond.

In this talk, we consider the question: given a set $X \subseteq \mathbb{R}^n$, does $N_r(X)$ have an inverse operation? With Vakil's childhood doodle in mind, define the radius r retraction of a set X, denoted $U_r(X)$, to be the set of points a distance greater than r away from every point outside of X. We explore the radius r retraction as a possible inverse to the radius r neighborhood. Surprisingly, $U_r(N_r(X)) = X$ only under certain hypotheses. In particular, this problem has interesting ties to convex geometry. (Received September 15, 2014)

1106-52-2223 **Gábor Fejes Tóth**, **Ferenc Fodor*** (fodorf@math.u-szeged.hu) and **Viktor Vígh**. *The packing density of the n-dimensional cross-polytope.* Preliminary report.

In this talk, we establish upper bounds for the packing density of the n-dimensional regular cross-polytope in the case that $n \geq 7$. We use a modified version of Blichfeldt's method that is due to G. Fejes Tóth and W. Kuperberg. (Received September 16, 2014)

1106-52-2497 **Jeremy Newton*** (jnewto02@leeu.edu) and **Debra Mimbs**. *Counting the Unit Polyhedron Volumes in a Tetrahedral Construction.*

Arising from Eike Hertel's paper, {Reguläre Dreieckspflasterungen konvexer Polygone}, we discuss tiling a regular tetrahedron with unit tetrahedrons and octahedrons. Ordering the tetrahedral constructions by size produces the sequence of tetrahedron numbers, which represents the number of unit tetrahedron volumes in a tetrahedral construction, which is the sequence of cubic integers. Further, we explore by truncating a tetrahedron by cutting away its corners and discover a new sequence of integers. This work has importance in physics in the study of crystals.
(Received September 16, 2014)

1106-52-2755 **Ryan Gordon Trelford*** (rgtrelfo@ucalgary.ca), University of Calgary, Department of Mathematics and Statistics, 2500 University Drive NW, Calgary, Alberta T2N 1N4, Canada. *X-Raying 3-Dimensional Convex Bodies with Mirror Symmetry.*

Let K be a d-dimensional convex body. A point p on the boundary of K is said to be X-rayed along a line with direction vector $\mathbf{v}$ if the line through p with direction $\mathbf{v}$ intersects the interior of K. A collection of lines is said to X-ray K if every boundary point of K is X-rayed along one of the lines. The minimum number of lines required to X-ray K is called the X-ray number of K, and is denoted by $X(K)$. In 1994, Bezdek and Zamfirescu conjectured that $X(K) \leq 3 \cdot 2^{d-2}$ for any d-dimensional convex body K.

In this talk, we explain how the X-ray Conjecture is related to the famous Gohberg-Markus-Hadwiger Covering Conjecture. Then we verify the X-ray conjecture for planar convex bodies, showing that three lines are needed if, and only if, the convex body is a triangle. Finally, we prove that any 3-dimensional convex body exhibiting mirror symmetry also satisfies the X-ray Conjecture. (Received September 16, 2014)

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1106-53-48 **Michael Jablonski*** (mjablonski@math.ou.edu). *Non-compact, homogeneous Einstein spaces.*

In the 1970s, D. Alekseevskii conjectured that if G/K is a non-compact, homogeneous Einstein space with negative scalar curvature, then K is a maximal compact subgroup of G. In this talk, we will present the current state of knowledge, with evidence both for and against the conjecture. (Received May 28, 2014)

1106-53-82 **Magdalena D Toda*** (magda.toda@ttu.edu), Lubbock, TX 79409, and **Bhagya Athukorallage** (bhagya.athukoralla@ttu.edu), Lubbock, TX 79409. *Generalized Willmore surfaces and applications.*

Starting from a generalized Willmore energy functional which is justified from a physical viewpoint, we study certain generalized Willmore surfaces as minimizers of this type of energy. We use several geometric tools, which include a classical variational approach, as well as the Cartan frame method (Cartan forms). Several applications are provided, including some elastic surface models which present a special importance in microbiology, genetics and biophysics. (Received July 06, 2014)

1106-53-218 **Allie Ray*** (allie.ray@mavs.uta.edu). *From graphs to Lie algebras to nilmanifolds.* Preliminary report.

I will present if and only if conditions for extending a certain two-step nilpotent Lie algebra associated with a colored, directed graph to a three-step nilpotent Lie algebra. The two-step construction is a generalization of a method used by S. Dani and M. Mainkar. Three step nilpotent Lie algebras are more delicate to construct since the Jacobi equation becomes a consideration. In addition, starting with pairs of Schreier graphs of a Gassmann-Sunada triple, I will consider issues of isospectrality and isometry of the associated nilmanifolds. Methods used include graph theory, combinatorics, Lie theory, group actions, and differential geometry. (Received August 11, 2014)

1106-53-309 **Carlos Alberto Cadavid*** (ccadavid@eafit.edu.co), **Juan Diego Velez** (jdvelez@unal.edu.co) and **Jean Carlos Cortissoz** (jean.cortissoz@gmail.com). *Minimal Morse functions via the heat equation.* Preliminary report.

Let (M, g) be a closed Riemannian manifold that is homogeneous, in the sense that each pair of points have mutually isometric neighborhoods, and let Δ_g be its Laplace-Beltrami operator. The heat equation on (M, g) is $\frac{\partial f}{\partial t} = -\Delta_g(f)$ and for each initial condition u in $L^2(M)$ there exists a unique solution $f_t(\cdot) := f(\cdot, t)$ satisfying $f_0 = u$.

It has been observed in several examples that for generic u and large enough t, that f_t is a Morse function having the least number of critical points admitted by any Morse function on M. There are examples in which this phenomenon does not hold in the form just stated, but seems to take place if one perturbs the metric g a bit. In order to probe the validity of the statement in this latter form, computational experiments have been performed in which the Riemannian manifold and its Laplace-Beltrami operator have been approximated by a graph and its Laplacian operator.

This suggests that it is worth asking whether a similar phenomenon holds for graphs. (Received August 20, 2014)

1106-53-330 **Marisa Fernandez*** (marisa.fernandez@ehu.es), Universidad del Pais Vasco, Facultad de Ciencia y Tecnologia, Matematicas, Campus de Leioa, 48940 Leioa, Bilbao, Vizcaya, Spain. *Formality in Cosymplectic and Sasakian Geometries.*

One of the results of Deligne, Griffiths, Morgan and Sullivan states that any compact Kähler manifold is formal. The importance of formality in symplectic geometry stems from the fact that it allows to distinguish compact symplectic manifolds which admit Kähler metrics from those which do not.

In this talk, we study the formality for the odd-dimensional counterpart to Kähler and symplectic manifolds, namely for cokähler, Sasakian and cosymplectic manifolds. Compact cokähler manifolds are formal. For simply connected Sasakian manifolds we prove that all higher Massey products vanish. Nevertheless, we present examples of simply connected compact Sasakian manifolds of dimension $2n + 1 \geq 7$ which are non-formal because they have a non-zero triple Massey product. On the other hand, we give conditions under which a mapping torus has a non-zero triple Massey product. We apply this to prove that there are compact cosymplectic manifoldsof dimension $2n + 1 \geq 3$ and with first Betti number $b \geq 1$ which are non-formal excepting for $(2n + 1, b) = (3, 1)$. (Any compact manifold of dimension 3 and with first Betti number $b = 1$ is formal but not necessarily cokähler.) (Received September 13, 2014)

1106-53-479 **Romina M. Arroyo***, romina.arroyo@gmail.com, and **Ramiro A. Lafuente**, ramlaf@gmail.com. *The Alekseevskii conjecture in low dimensions.*

One of the most important open problems on Einstein homogeneous manifolds is the Alekseevskii conjecture, which states that any connected, non-compact, homogeneous Einstein manifold must be diffeomorphic to a Euclidean space. Up to now, it was known that the conjecture was true only up to dimension 5, and in dimension 6 when the transitive group is not semisimple. The purpose of this talk is to show that the conjecture holds up to dimension 8 (excluding the case of semisimple Lie groups), and up to dimension 10 when the transitive group is not semisimple. (Received August 29, 2014)

1106-53-505 **Hiroshi Tamaru*** (tamaru@math.sci.hiroshima-u.ac.jp), Department of Mathematics, Hiroshima University, Higashi-Hiroshima, 739-8526, Japan. *The space of left-invariant metrics and submanifold geometry.*

It is an important problem to examine whether a given Lie group admit distinguished left-invariant metrics, such as Einstein or Ricci soliton metrics. In this talk, I will explain our approach from submanifold geometry. In particular, for three-dimensional solvable Lie groups, the existence and nonexistence of left-invariant Ricci soliton metrics have a nice correspondence with the geometry of cohomogeneity one actions on some noncompact symmetric space. I will also mention some higher-dimensional examples and a pseudo-Riemannian version. (Received August 31, 2014)

1106-53-515 **Christina Wiis Tonnesen-Friedman*** (tonnesec@union.edu), Department of Mathematics, Bailey Hall, Union College, Schenectady, NY 12308. *Ricci curvature in Sasakian and Kaehler Geometry.*

This talk will be a discussion of the role of Ricci curvature in Sasakian and Kaehler geometry. In particular we will focus on Sasaki structures arising from the join construction. The talk is based on joint work with Charles Boyer. (Received September 01, 2014)

1106-53-547 **Xiaodong Wang*** (xwang@math.msu.edu). *Boundary effect of Ricci curvature.*

On a compact Riemannian manifold with boundary, we study how Ricci curvature of the interior affects the geometry of the boundary. First we establish integral inequalities for functions defined solely on the boundary and apply them to obtain geometric inequalities involving the total mean curvature. Then we discuss related rigidity questions and prove Ricci curvature rigidity results for manifolds with boundary.

This is joint work with Pengzi Miao at University of Miami. (Received September 02, 2014)

1106-53-602 **Ian M. Adelstein***, Department of Mathematics, Dartmouth College, Hanover, NH 03755. *Existence and Non-existence of Half-Geodesics on S^2.*

In this talk we will discuss 1/k-geodesics, those closed geodesics that minimize on any subinterval of length $l(\gamma)/k$. Christina Sormani has shown that the 1/k-geodesics persist under the Gromov-Hausdorff convergence of Riemannian manifolds. We use her result to construct manifolds diffeomorphic to S^2 that admit exactly n half-geodesics (1/2-geodesics) for each nonnegative integer n. Additionally, we construct a sequence of manifolds, each of which is diffeomorphic to S^2 and admits no half-geodesics, yet which converge in the Gromov-Hausdorff sense to a limit space admitting infinitely many half-geodesics. (Received September 03, 2014)

1106-53-620 **Carolyn Gordon***, csgordon@dartmouth.edu, and **Michael Jablonski**. *Einstein solvmanifolds have maximal symmetry.* Preliminary report.

We prove that any non-flat left-invariant Einstein metric g on a solvable Lie group S is maximally symmetric. More precisely, if h is any other left-invariant Riemannian metric on S, then there exists an automorphism ψ of S such that the full isometry group of h is contained in that of the Einstein metric ψ^*g. The proof exploits the deep relationship between left-invariant Einstein metrics of negative Ricci curvature on solvable Lie groups and geometric invariant theory.

Alekseevskii conjectured that every homogeneous Einstein manifold of negative Ricci curvature is isometric to a solvable Lie group with a left-invariant Einstein metric. We will discuss the theorem above both in the context of this conjecture and in the context of finding the "best" left-invariant Riemannian metric on a given Lie group. (Received September 03, 2014)

1106-53-683 **Karsten Grove*** (kgrove2@nd.edu) and **Xiaoyang Chen**. *Rigidity Theorems for Submetries in Positive Curvature.*

We derive general structure and rigidity theorems for submetries f from a Riemannian manifold M with sectional curvature ≥ 1. When applied to a non-trivial Riemannian submersion, it follows that the diameter of the base is at most $\pi/2$. In case of equality, there is a Riemannian submersion from a unit sphere, and as a consequence, f is known up to metric congruence. A similar rigidity theorem also holds in the general context of Riemannian foliations. (Received September 04, 2014)

1106-53-694 **Patrick B Eberlein*** (pbe@email.unc.edu), Department of Mathematics, CB # 3250, University of North Carolina, Chapel Hill, NC 27599. *Two-step nilpotent Lie groups with prescribed Ricci tensor.*

Abstract Fix a pair of positive integers (p,q). We obtain a lower bound in terms of p,q for the dimension of the space of isometry classes of metric 2-step nilpotent Lie algebras $\{\mathfrak{N}, \langle , \rangle\}$ of type (p,q) with a fixed Ricci tensor. We also consider two special types of Ricci tensors : optimal and geodesic flow invariant, where the first is an example of the second. We show that if (p,q) $\neq$ (2,2k+1) or its dual (D-2,2k+1), where D = (1/2)(2k+1)(2k), then a generic 2-step nilpotent Lie algebra $\mathfrak{N}$ of type (p,q) admits an inner product $\langle,\rangle$ whose Ricci tensor is optimal. This result has also been obtained by Y. Nikolaevsky. (Received September 04, 2014)

1106-53-771 **Ryad A Ghanam*** (raghanam@vcu.edu), Doha, Qatar. *Representations of Low Dimensional Lie Algebras and Applications.* Preliminary report.

In this talk I will report on the progress of the problem of finding linear representation for low-dimensional Lie algebras. For each Lie algebra of dimension less than or equal to six, we will give a matrix Lie group whose Lie algebra is the given algebra in the list. I will also report on the progress of the finding representations for the seven-dimensional nilpotent Lie algebras. As an application, I will show how Lie algebra plays a major role in understanding and solving partial differential equations. (Received September 06, 2014)

1106-53-929 **Lina Wu*** (lwu@bmcc.cuny.edu), 529 West 42nd Street Apt. 5K, New York, NY 10036. *Studying the Harmonic Differential Forms under Appropriate Growth Estimates by Extending the Scope of L^q to Non-L^q Space.* Preliminary report.

- It is well-known that on a compact Riemannian manifold, a differential form ω is closed (i.e. $d\omega = 0$) and co-closed (i.e. $d^*\omega = 0$) if and only if it is harmonic (i.e. $\triangle\omega = (dd^* + d^*d)\omega = 0$).
$$\triangle\omega = 0 \Longleftrightarrow d\omega = d^*\omega = 0$$
- On a complete non-compact Riemannian manifold, A.Andreotti and E.Vesentini proved the equivalence between a differential harmonic form and a closed co-closed differential form in L^q space for $q = 2$.
- In this talk, we will discuss the equivalence between a harmonic form and a closed co-closed form on a complete non-compact Riemannian manifold that is not necessarily in L^2 space and is not necessarily in L^q space for any $q \neq 2$. We generalize the work of A.Andreotti and E.Vesentini. This is my joint work with Dr. Shihshu Walter Wei.

(Received September 08, 2014)

1106-53-941 **Marisa Fernández**, Universidad del País Vasco, **Stefan Ivanov**, University of Sofia "St. Kl. Ohridski", **Luis Ugarte**, Universidad de Zaragoza, and **Dimiter Vassilev*** (vassilev@unm.edu), University of New Mexico. *Heterotic String Solutions with non-constant dilaton.*

We investigate smooth solutions with non-trivial fluxes to the heterotic equations of motion preserving at least one supersymmetry up to the first order of the string tension α'. The focus will be on the geometric structures and partial differential equations in the G_2-heterotic case and its relation with solutions in lower dimensions. (Received September 09, 2014)

1106-53-948 **Yuri Nikolayevsky*** (y.nikolayevsky@latrobe.edu.au), Department of Mathematics and Statistics, La, Trobe University, Bundoora, Melbourne, Victoria 3195, Australia. *Solvable Lie groups of negative Ricci curvature.*

We consider solvable Lie groups which admit a left-invariant metric of strictly negative Ricci curvature. We obtain necessary and sufficient conditions of the existence of such a metric for Lie groups the nilradical of whose Lie algebra is either abelian or Heisenberg or filiform and discuss some open questions. (Received September 09, 2014)

1106-53-985 **Michael Bradford Williams***, UCLA Mathematics Department, Box 951555, Los Angeles, CA 90095-1555, **Michael Jablonski**, Department of Mathematics, University of Oklahoma, Norman, OK 73019-3103, and **Peter Petersen**, UCLA Mathematics Department, Box 951555, Los Angeles, CA 90095-1555. *On the stability of expanding Ricci solitons.*

In previous work, the authors studied the linear stability of algebraic Ricci solitons on simply connected solvable Lie groups (solvsolitons), which are stationary solutions of a certain normalization of Ricci flow. Many examples were shown to be linearly stable, leading to the conjecture that all solvsolitons are linearly stable. This paper makes progress towards that conjecture, showing that expanding Ricci solitons with bounded curvature (including solvsolitons) are linearly stable after extension by a Gaussian soliton. As in the previous work, the dynamical stability of each metric follows from a generalization of the techniques of Guenther, Isenberg, and Knopf. (Received September 09, 2014)

1106-53-1018 **Guofang Wei***, Dept. of Math, UCSB, Santa Barbara, CA 93101. *Universal Covers of Spaces with Curvature Bounded from Below.*

We observe that any metric measure space satisfying the Riemannian curvature dimension condition (RCD(K,N), with N finite) has a universal covering space. This extends joint work with C. Sormani in which we proved that the universal cover of the Gromov-Hausdorff limit of n-dim manifolds with Ricci curvature bounded below exists. (Received September 09, 2014)

1106-53-1033 **William Wylie*** (wwylie@syr.edu). *Positive weighted Sectional Curvature.*

We propose a new generalization of positive sectional curvtaure we call positive weighted sectional curvature, which depends on the choice of a smooth vector field on a Riemannian manifold. The definition is motivated by the correspoinding notion of Ricci curvature for manifolds with density which was developed by Bakry-Emery and their collaborators and appears, for example, in the Ricci soliton equation. We show that many basic results for positive curvature also hold for positive weighted curvature. For example, positive weighted curvature is preserved by Riemannian submersions and Synge-type theorems hold. We also show that topological classifications results of Grove-Searle and Wilking on compact manifolds of high symmetry rank and positive curvature can be generalized to positive weighted curvature.

This is joint work with Lee Kennard of UCSB. (Received September 09, 2014)

1106-53-1046 **Jo Nelson*** (nelson@math.columbia.edu) and **Micheal Hutchings**. *Cylindrical Contact Homology: An Abridged Restrospective.* Preliminary report.

Cylindrical contact homology is arguably one of the more notorious Floer theoretic constructions. The past decade has been less than kind to this theory, as the growing knowledge of gaps in its foundations have tarnished its claim to being a well-defined contact invariant. However, recent work of Hutchings and Nelson has managed to redeem this theory in dimension 3 for dynamically convex contact manifolds. This talk will highlight our implementation of intersection theory, non-equivariant constructions, domain dependent almost complex structures, automatic transversality, and obstruction bundle gluing, yielding a homological contact invariant which is expected to be isomorphic to SH^+ under suitable assumptions, though does not require a filling of the contact manifold. By making use of family Floer theory we obtain a S^1-equivariant theory defined over Z-coefficients, which when tensored with Q yields cylindrical contact homology, now with the guarantee of well-definedness and invariance. (Received September 10, 2014)

1106-53-1119 **David Alan Glickenstein*** (glickenstein@math.arizona.edu), Department of Mathematics, 617 N Santa Rita, Tucson, AZ 85721. *The RG-2 bracket flow on Lie groups and related flows.* Preliminary report.

The RG-2 flow is the two-loop approximation of renormalization group flow for nonlinear sigma models, and serves as a natural extension of Ricci flow (which would be RG-1 flow). We will explore the RG-2 flow on homogenous spaces, primarily restricting to left invariant metrics on 3D unimodular Lie groups, by looking at the induced flows on the Lie brackets structure constants for an orthonormal left invariant frame. The bracket flow formulation has the advantage of turning many soliton (self-similar) solutions into fixed points. We will also consider related flows to RG-2 flow that exhibit additional fixed points. We take the viewpoint that the RG-2 flow and other flows are perturbations of the Ricci flow and consider these flows in this context. (Received September 10, 2014)

1106-53-1122 **Peter Spaeth***, One Research Circle, K1-454A, Niskayuna, NY 12309. *The symplectic displacement energy.*

We define a symplectic displacement energy for subsets of a symplectic manifold via Banyaga's Hofer-like metric on the identity component of the group of symplectic diffeomorphisms. This generalizes a theorem of Eliashberg-Polterovich for the Hofer displacement energy. The talk is based on a joint work with Augustin Banyaga and David Hurtubise. (Received September 10, 2014)

1106-53-1243 **Caitlin Leverson*** (cleverso@math.duke.edu). *Legendrian Knots, Augmentations, and Rulings.*

A Legendrian knot in $\mathbb{R}^3$ with the standard contact structure is a knot for which dz-ydx=0. Given a Legendrian knot, one can associate the Chekanov-Eliashberg differential graded algebra (DGA) over $\mathbb{Z}/2$. Fuchs and Sabloff showed there is a correspondence between augmentations to $\mathbb{Z}/2$ of the DGA and rulings of the knot diagram. Etnyre, Ng, and Sabloff showed that one can define a lift of the Chekanov-Eliashberg DGA over $\mathbb{Z}/2$ to a DGA over $\mathbb{Z}[t,t^{-1}]$. This talk will give an extension of the relationship between rulings and augmentations to $\mathbb{Z}/2$ of the DGA over $\mathbb{Z}/2$, to a relationship between rulings and augmentations to a field of the DGA over $\mathbb{Z}[t, t^{-1}]$. No knowledge of the Chekanov-Eliashberg DGA will be assumed. (Received September 11, 2014)

1106-53-1317 **Mustafa Kalafat*** (mkalafat@tunceli.edu.tr). *Conformally Kähler Surfaces and Orthogonal Holomorphic Bisectional Curvature.*

We show that a compact complex surface which admits a conformally Kähler metric g of positive orthogonal holomorphic bisectional curvature is biholomorphic to the complex projective plane. In addition, if g is a Hermitian metric which is Einstein, then the biholomorphism can be chosen to be an isometry via which g becomes a multiple of the Fubini-Study metric. This is a joint work with C. Koca. (Received September 12, 2014)

1106-53-1370 **David E. Blair*** (blair@math.msu.edu), MI. *Conformal and Bochner flatness in complex contact geometry and in the geometry of metric contact pairs.* Preliminary report.

First we review the geometry of complex contact manifolds as defined locally by a holomorphic contact form and the geometry of contact pairs (also known as bicontact manifolds). We also will review the Bochner tensor in the general almost Hermitian setting.

In joint work with V. Martín-Molina we showed that there are no conformally flat, normal, complex contact metric manifolds and that a Bochner flat, normal, complex contact metric manifold must be Kähler and its universal cover is $\mathbb{C}P^n(4)$. We then discuss joint work with G. Bande and A. Hadjar and give our results to date on conformally flat and Bochner flat, normal, metric contact pairs. Here the Hopf manifolds $S^{2n+1}(1) \times S^1$ are both conformally flat and Bochner flat. (Received September 12, 2014)

1106-53-1395 **Christopher Stuart Inbody*** (csinbody@unm.edu), 6301 Lamy St NW, Albuquerque, NM 87120. *Positive Sasakian structures on 5 and 7 dimensional links of hypersurface singularities and isolated complete intersection singularities in weighted projective space.* Preliminary report.

Links of isolated singularities defined by weighted homogeneous polynomials have a natural Sasakian structure. Since it is known that Sasaki-Einstein metrics have positive Ricci curvature, and since positive Sasakian structures give rise to Sasakian metrics with positive Ricci curvature, it is useful to determine which links have a positive Sasakian structure. This corresponds to the Fano index of the associated weighted projective variety being positive. Links of dimension $2n-1$ are $(n-2)$-connected. Complete results for dimension 3 were obtained by Milnor, Orlik, and Arnol'd. A complete result for hypersurface singularities with positive Sasakian links of dimension 5 was provided by Yau and Yu. This paper investigates isolated singularities of codimension 2 complete intersections with 5 dimensional links of positive index and some higher dimensional results. (Received September 12, 2014)

1106-53-1678 **Arthur E. Fischer*** (aef@ucsc.edu), Department of Mathematics, University of California, Santa Cruz, CA 95064. *Conformal Ricci Flow, Navier-Stokes Equations, and Conformal Reduction of Einstein's Evolution Equations of General Relativity.*

We introduce a variation of the classical normalized Ricci flow equations that modifies the *volume constraint* of those equations to a *scalar curvature constraint*. The resulting equations are named the *conformal Ricci flow equations* because of the role that conformal geometry plays in constraining the scalar curvature. These new equations are given by

$$\begin{aligned} \frac{\partial g}{\partial t} + 2\big(\mathrm{Ric}(g) + \tfrac{1}{n} g\big) &= -pg \\ R(g) &= -1 \end{aligned}$$

for a dynamically evolving metric g and a non-dynamical scalar field p, known as the *conformal pressure*. The conformal Ricci flow equations are analogous to the Navier-Stokes equations of fluid mechanics

$$\begin{aligned} \frac{\partial v}{\partial t} + \nabla_v v + \nu \Delta v &= -\mathrm{grad}\ p \\ \mathrm{div}\ v &= 0 \end{aligned}$$

Just as the real physical pressure in fluid mechanics serves to maintain the incompressibility constraint of the fluid, the conformal pressure serves as a Lagrange multiplier to conformally deform the metric flow so as to maintain the scalar curvature constraint. The conformal Ricci flow equations can be thought of as Navier-Stokes equations for the metric and also as a parabolic model for the *conformally reduced Einstein evolution equations*. (Received September 14, 2014)

1106-53-1724 **Luis Ugarte*** (ugarte@unizar.es), Departamento de Matematicas, Instituto de Matematicas y Aplicaciones -IUMA, Universidad de Zaragoza, 50009 Zaragoza, Spain. *Special Hermitian metrics on compact complex manifolds and holomorphic deformations.*

In this talk we focus on the interaction of several complex invariants and metric properties of compact complex manifolds, as well as their behaviour under holomorphic deformations. Strongly Gauduchon (sG) metrics were introduced by Dan Popovici and they constitute an important class of metrics lying between the balanced Hermitian and the usual Gauduchon metrics. Recently, a new class of compact complex manifolds, the sGG class, given by those manifolds whose Gauduchon cone coincides with the sG cone has been considered, and numerical characterizations of sGG manifolds involving certain Hodge, Bott-Chern and Betti numbers are given. We exhibit the relations among the balanced, sG and sGG manifolds and other properties like the $\partial\bar{\partial}$-lemma or the degeneration of the Frölicher spectral sequence. Motivated by the study of deformation limits of *class* C manifolds, we also show the behaviour of these properties under holomorphic deformations. (The talk is based on results obtained in collaboration with M. Ceballos, A. Fino, D. Popovici, A. Otal and R. Villacampa.) (Received September 15, 2014)

1106-53-2132 **Chenxu He*** (che@math.ou.edu). *Geometry of gradient Ricci solitons.*

Ricci solitons are self-similar solutions to Hamilton's Ricci flow and they play a particular role in the singularity analysis of Ricci flow. They are also natural generalization of Einstein manifolds. We present a few results in the study of geometry of gradient Ricci solitons, including the stability problem for the shrinking Ricci solitons with respect to Perelman's shrinker entropy and show the classification on symmetric spaces of compact type, and the deformation of steady gradient Ricci solitons and show that the infinitesimal deformation is trivial in low dimension. This is a joint work with Huai-Dong Cao. (Received September 15, 2014)

1106-53-2141 **Donovan Clark McFeron***, dmcferon@ramapo.edu. *The twisted Kähler-Ricci Hermitian Yang-Mills flow.* Preliminary report.

In this talk, we we introduce the twisted Kähler-Ricci Hermitian Yang-Mills flow on a compact Kähler manifold.

$$\begin{cases} \frac{\partial}{\partial_t} g = -Ric(g) + F_A; \\ \frac{\partial}{\partial_t} A = -d^* F \end{cases}$$

The interest in this coupled flow lies in the fact that its fixed points will have constant scalar curvature metrics. In this talk we will discuss its short time existence and under which conditions it has long time existence. (Received September 15, 2014)

1106-53-2190 **Alfredo Villanueva*** (villanuevaa@savannahstate.edu), Savannah State University, Department of Mathematics, PO BOX 20047, Savannah, GA 31404. *Explicit Solutions of the Schrodinger Equation on Families of Riemannian Manifolds.*

The study of separation of variables on Riemannian manifolds, is an active research area, and still unsolved in general settings. In this paper, we show explicit solutions for the Schrodinger equation in Darboux type Manifolds. Our approach is the use of separation of variables after a suitable change of variables. We also study the geometry of these manifolds. (Received September 16, 2014)

1106-53-2219 **Albert J. Todd*** (ajtodd@southalabama.edu). *Almost Contact Structures and G_2-Manifolds.* Preliminary report.

Arikan, Cho and Salur proved that any 7-manifold with G_2-structure admits an almost contact structure which is compatible with the G_2-metric. In this talk I will review this construction then show that on a G_2-manifold, that is, a 7-manifold with integrable G_2-structure, their construction leads to a normal almost contact structure if the characteristic vector field is a Killing vector field for the G_2-metric. This has some immediate consequences regarding CR-structures and cosymplectic structures on a G_2-manifold. Finally, I will show that these ideas can be extended to give an almost contact 3-structure on a compact G_2-manifold without boundary. (Received September 16, 2014)

1106-53-2412 **Rebecca Glover*** (rglover3@ur.rochester.edu), University of Rochester, Rochester, NY 14627. *Geometry and topology of G_2 and $Spin(7)$ submanifolds.* Preliminary report.

G_2 and Spin(7) manifolds are seven and eight-dimensional manifolds of special holonomy that can locally be described by the geometry of the octonions. In this talk, we will discuss certain vector-valued differential forms on G_2 and Spin(7) manifolds. We look at their local description and explain what these forms can illustrate about the geometry and topology of the underlying manifolds. (Received September 16, 2014)

1106-53-2436 **Jeffrey Jauregui***, jaureguj@union.edu. *Symmetries of generalized Ricci solitons.* Preliminary report.

Gradient Ricci solitons have a number of significant generalizations, including almost Ricci solitons, static metrics, and quasi-Einstein metrics. I will discuss results on the symmetries of such objects, particularly on how symmetries of the potential function relate to symmetries of the underlying geometry. (Received September 16, 2014)

1106-53-2438 **Ibrahim Unal*** (uibrahim@metu.edu.tr), Middle East Technical University, Northern Cyprus Campus, Kalkanli, Mersin 10 Guzelyurt, Turkey. *Critical Values of Calibrations and Minimal Submanifolds.*

On a calibrated manifold M with differential p-form φ as the calibration, calibrated submanifolds i.e. φ-submanifolds are globally volume minimizing in their homology classes. Thus, they are a very good source of minimal submanifolds. These are the submanifolds corresponding to the global maximum value of the calibration φ when considered as a function on Grassmannian bundle of oriented p-planes of M. In this talk, I will explain that submanifolds corresponding to any non-zero critical value of a calibration, namely φ-critical submanifolds, are also minimal under some additional conditions about either the calibration φ or the critical value. Furthermore, I will give some examples of φ-critical submanifolds. (Received September 16, 2014)

1106-53-2653 **T. H. Wears*** (wearsth@longwood.edu). *Lorentzian Ricci Solitons On Nilpotent Lie Groups.* Preliminary report.

We present the classification of left invariant Lorentzian metrics on two different five-dimensional, simply-connected, two-step nilpotent Lie groups and investigate the curvature properties of the resulting families of metrics, paying special attention to those metrics that are Ricci solitons and/or algebraic Ricci solitons. In particular, we give a complete classification of the Ricci soliton structures on each of the Lie groups in question, showing that in sharp contrast with left invariant Riemannian metrics on nilpotent Lie groups, a given nilpotent Lie group can support a variety of inequivalent Lorentzian Ricci solitons and that not all Ricci solitons are algebraic Ricci solitons. Time permitting, we will outline a generalization of the classifications to all odd dimensions. (Received September 16, 2014)

1106-53-2671 **Igor Zelenko*** (zelenko@math.tamu.edu), Department of Mathematics, Mailstop 3368, College Station, TX 77843. *Symplectically flat vector distributions and their symmetries.*

Vector distributions constitute a very natural and wide class of geometries that can be defined by differential forms. They appear naturally in control theory and geometric theory of differential equations. Apart of several cases of small rank or corank, local differential geometry of vector distribution is not trivial. In the last decade we developed the novel variational or symplectic approach for the construction of canonical frames and differential invariants for a very wide class of distributions. The main new point of this approach is that the study of geometry of distributions can be reduced to a simpler (extrinsic) geometry of curves of symplectic flags. In terms of these curves we obtain a new discrete basic invariant of the original distribution, called the flag symbol and we have an explicit algorithm for construction of the canonical frame for our original structure that depends only on first fixing this discrete information. In this talk I would like to focus on the following two questions: what are the most simple distributions with given flag symbol and what is their group of symmetries. (Received September 16, 2014)

1106-53-2799 **Sharif Ibrahim*** (jmm2015@sharifibrahim.com), **Bala Krishnamoorthy** and **Kevin R. Vixie**. *Flat norm decomposition of integral currents.*

Currents (dual to differential forms) can be thought of as oriented generalized surfaces. The flat norm provides a useful distance in this space based on decomposing d-currents into d-dimensional pieces and (boundaries of) $(d+1)$-dimensional pieces in an optimal way. One question is whether regularity in the input current implies regularity of the decomposition. In particular, do integral currents necessarily have integral decompositions? This is known for boundaries of codimension 1 and recently in a discretized problem for codimension 1 chains (which need not be boundaries). This work presents a framework that bridges the gap between the continuous and discrete settings, relying only on the existence of a triangulation quality result which is explicitly shown for 1-currents in the plane based on a result of Shewchuk. (Received September 16, 2014)

1106-53-2891 **Karsten Gimre*** (gimre@math.columbia.edu), 2990 Broadway, New York, NY 10027, New York, NY 10027. *Second order renormalization group flow.*

The second order renormalization group flow,

$$\frac{\partial g_{ij}}{\partial t} = -2R_{ij} - \alpha R_{iklm} R_j{}^{klm},$$

is a generalization of the Ricci flow arising from renormalization of the nonlinear sigma model in quantum field theory. We will discuss various issues related to existence of the flow as well as soliton solutions. (Received September 17, 2014)

54 ► General topology

1106-54-109 **Jason Haarmann** and **Meg P Murphy***, meg.page.murphy@gmail.com, and **Casey S Peters** and **P Christopher Staecker**. *Homotopy equivalence of finite digital imnages.*

For digital images, there is an established homotopy equivalence relation which parallels that of classical topology. Many classical homotopy equivalence invariants, such as the Euler characteristic and the homology groups, do not remain invariants in the digital setting. This paper develops a numerical digital homotopy invariant and begins to catalog all possible connected digital images on a small number of points, up to homotopy equivalence. (Received July 17, 2014)

1106-54-312 **Zahra Sinaei***, sinaei@cims.nyu.edu, and **Christina Sormani**. *Almost Homotopies and Intrinsic Flat Convergence.*

Covering spaces of topological manifolds are defined as homotopy equivalent classes of curves with a fixed endpoint. Epsilon-covering spaces of a metric space are defined as epsilon almost homotopy equivalent classes of epsilon chains of points with a fixed endpoint [Beretovskii-Plaut]. These covering spaces were shown to be equivalent to the Sormani-Wei delta covering spaces of geodesic metric spaces by Plaut Wilkins. Sormani-Wei proved that when a sequence of geodesic metric spaces converges in the Gromov-Hausdorff sense, then the delta covering spaces converge to a cover of the limit spaces. Here we study sequences of Riemannian manifolds without boundary with finite fundamental groups and prove that if such Riemannian manifolds converge in the intrinsic flat sense to a connected limit space then a subsequence of their delta covers converges to a disjoint union of isometric connected covering spaces of the limit space. This is joint work with C. Sormani. (Received August 20, 2014)

1106-54-400 **Koushik Pal*** (`koushik.pal@usask.ca`) and **Samer Assaf** (`samerassaf@hotmail.com`). *Partial metric spaces with negative distances and fixed point theorems.* Preliminary report.

Metric spaces have been studied by mathematicians for ages. Their importance in several areas of mathematics cannot be overemphasized. About two decades ago, Steve Matthews introduced a major generalization of metric spaces, where the distance between a point x and itself, called the *self distance of* x, is not necessarily zero. He called them *partial metric spaces*. He went on further to prove an analogue of the Banach Fixed Point Theorem for such spaces. Very recently, we have introduced a major generalization of partial metric spaces, where we not only allow for nonzero self distances, but also allow for "negative distances". We call such spaces *generalized partial metric spaces*. Such metrics have a strong connection with "scoring functions" in biology. In this talk, we will start with a motivation for using negative values. Then we will present a generalization of the partial metric fixed point theorem in this generalized context, which is a generalization in several ways. And finally, we will also present a further generalization of metric spaces, called the *strong partial metric spaces*, which are much nicer than partial metric spaces at least as far as some of the fixed point theorems are concerned. (Received August 27, 2014)

1106-54-642 **Shaun G. Benvie*** (`sgbenvie@gmail.com`), **Owen S. Hill** (`oshill93@gmail.com`) and **Elizabeth T. Brown** (`brownet@jmu.edu`). *Partial Metric Spaces: Representation and Classification.*

Partial metrics generalize the standard notion of distance, a metric, to allow for non-zero self-distances. We show how partial metrics can be constructed from standard metrics and vice versa, which gives rise to a useful representation theorem. We also examine partial metric topologies, which are not in general metrizable. We analyze the separation axioms and the properties of sequences and limits in this setting. (Received September 12, 2014)

1106-54-804 **Nate Ackerman*** (`nate@math.harvard.edu`), Mathematics Department, Harvard University, One Oxford Street, Cambridge, MA 02138. *A Fixed Point Theorem for Spherically Complete V-Continuity Spaces.*

In this talk we will present a result which has both the Priess-Crampe and Ribenboim fixed point theorem and the Banach fixed point theorem (for spherically complete spaces) as special cases. Specifically if V is a quantale the notion of a V-continuity space generalizes that of a metric space. We prove an analog of the Banach fixed point theorem which holds for all spherically complete symmetric separated V-continuity spaces. As it has been shown by Flagg that all topological spaces arise as V-continuity spaces our fixed point theorem applies in many more situations than either the Banach fixed point theorem or the Priess-Crampe and Ribenboim fixed point theorem.

If there is time we will also discuss some counterexamples which show that most of our assumptions cannot be weakened. (Received September 07, 2014)

1106-54-1093 **Molly A Moran*** (mamoran@uwm.edu). *Metrics on CAT(0) Boundaries.*

An example of Croke and Kleiner shows that CAT(0) group boundaries are not well-defined. That is, a CAT(0) group can have two non-homeomorphic boundaries. Thus, one might hope to study CAT(0) boundaries from a geometric or analytic standpoint, since a purely topological approach is insufficient. However, there is no "natural" metric on the boundary. We will discuss potential metrics that could be used along with some of their properties. (Received September 10, 2014)

1106-54-2766 **Dylan Peifer** (djp282@cornell.edu), **Martin D. Bobb*** (mbobb@math.utexas.edu), **Helen Wong** (hwong@carleton.edu) and **Stephen Kennedy** (skennedy@carleton.edu). *A Finite Set of Generators for the Arc Algebra.*

Let $F_{g,n}$ denote the compact orientable 2-manifold with genus g and n punctures. The arc algebra of $F_{g,n}$, developed by Roger and Yang in 2011, is a generalization of the Kauffman bracket skein algebra that allows for framed arcs between punctures. In this paper we generalize results of Doug Bullock on the skein algebra to find a finite set of generators for the arc algebra of $F_{g,n}$. This generating set consists only of arcs for the punctured sphere and is also significantly smaller than the generating set of the skein algebra when the surface has 5 or more punctures. (Received September 16, 2014)

55 ► Algebraic topology

1106-55-156 **Kristine Pelatt***, 2004 Randolph Ave, Saint Paul, MN 55105. *Geometric homology classes in the space of knots.*

Using the calculus of functors, Sinha found spectral sequences converging to the homology and cohomology of knot spaces. These spectral sequences, however, do not immediately give representatives of cycles and cocycles. Generalizing methods of Cattaneo, Cotta-Ramusino, and Longoni, we develop a method of describing representatives of cycles in the space of knots by resolving intersection points on singular knots. The method of resolution is dictated by the combinatorics of the homology spectral sequence. In particular, we describe geometric representatives of non-trivial $3(d-8)$-dimensional cycles and cocycles, which guide our search for additional geometric representatives of cycles and cocycles. (Received July 31, 2014)

1106-55-158 **Mustafa Hajij*** (mhajij1@math.lsu.edu), Louisiana State University, Baton Rouge, LA 70808. *Skein Theory and q-series.*

The tail of the colored Jones polynomial is a q-power series invariant. We use the skein theory associated with the Kauffman bracket skein module to understand the tail of the colored Jones polynomial. we generlize this study further to trivalent graphs and study their tail using skein theory. In most cases, it turns out that the tail these trivalent graphs are interesting number-theoretic q-series. In particular, certain trivalent graphs give a skein theoretic proof for the Andrews-Gordon identities for the two variable Ramanujan theta function as well to corresponding identities for the false theta function. Finally, we give a product formula that the tail of such graphs satisfies. (Received August 01, 2014)

1106-55-189 **Anna Marie Bohmann*** (bohmann@math.northwestern.edu), Department of Mathematics, 2033 Sheridan Road, Evanston, IL 60208, and **Angelica M. Osorno**. *Constructing equivariant spectra.*

Equivariant spectra determine cohomology theories that incorporate a group action on spaces. Such spectra are increasingly important in algebraic topology but can be difficult to understand or construct. In recent work, Angelica Osorno and I have created a machine for building such spectra out of purely algebraic data based symmetric monoidal categories. In this talk I will discuss an extension of our work to the world of Waldhausen categories. This new construction is more flexible and is designed to be suitable for equivariant algebraic K-theory constructions. (Received August 06, 2014)

1106-55-243 **Safia Chettih***, Dept of Mathematics, University of Oregon, Eugene, OR 97403. *Topology of Configurations on Graphs.*

The homology and cohomology groups of ordered configurations are known on a number of simple graphs. I will give explicit presentations for the (co)homology of ordered and unordered configurations of two points, along with intersection pairings, on k-pronged graphs and trivalent trees, and discuss the geometrical/combinatorial structures which relate the presentations. (Received August 14, 2014)

1106-55-284 **Pawel Dlotko*** (dlotko@sas.upenn.edu). *Persistent homology as a practical characteristic of scalar valued functions defined on topological spaces.*

Persistent homology provide an elegant way of describing changes in homology of level sets of a scalar value function defined on finite cell complexes.

There were two main obstacles to use this idea to practically characterize a topological space with a function on it:

(1) There were no algorithms to compute persistence of a continuous subsets of a topological space with a given error tolerance.

(2) There were no efficient ways to compare persistence diagrams.

In this talk I will remind the concept of persistence homology and describe how to rigorously compute persistence of a subspace of R^n. I will also present an efficient way of computing distances, averages and other statistics of persistence and use the presented machinery to analyze patterns obtained form Cahn-Hiliard-Cook and Diblock-Copolymer equations.

This is a joint work with Peter Bubenik, Thomas Wanner and Thomas Stephens. (Received August 19, 2014)

1106-55-342 **Sarah A Yeakel*** (yeakel2@illinois.edu). *Classifying n-excisive functors by generic representations.*

In the calculus of functors, Goodwillie has given a way to approximate a functor with a Taylor tower of polynomial functors. Kuhn classified degree n functors of vector spaces by modules over matrix rings, which he calls generic representations. This result was generalized by McCarthy for endofunctors of module spectra, and we will discuss a further generalization of Kuhn's result to n-excisive functors from nice simplicial model categories to spaces or spectra. Motivated by Bökstedt's construction for THH, we use a slight modification to Goodwillie's construction of the n-th Taylor polynomial that admits the extra structure needed to obtain the result. (Received August 23, 2014)

1106-55-347 **Mona Merling*** (mmerling@jhu.edu). *New developments in equivariant algebraic K-theory.* Preliminary report.

There is a rapidly evolving development of equivariant infinite loop space theory which is expected to have long-range applications to algebraic K-theory. I will give a brief overview of motivations, results, and prospects. (Received August 24, 2014)

1106-55-351 **Irina Bobkova*** (irina.bobkova@gmail.com). *Computations in the $K(2)$-local category at the prime 2.*

Chromatic homotopy theory describes the homotopy of the p-local sphere spectrum S through a family of localizations $L_{K(n)}S$ with respect to Morava K-theories $K(n)$. Considerable information about $L_{K(n)}S$ can be derived from the action of the Morava stabilizer group on the Lubin-Tate theory. One of the major computational tools is breaking up the homotopy of $L_{K(n)}S$ using various finite subgroups of the Morava stabilizer group. We will discuss some recent results and computations in the $K(2)$-local category at the prime $p = 2$. (Received August 24, 2014)

1106-55-480 **Sam Nariman*** (nariman@math.stanford.edu), 736 Escondido Road #231, Stanford, CA 94305. *Homological stability of diffeomorphim groups made discrete.*

We prove that group homology of the diffeomorphism group of $\#^g S^n \times S^n$ as a discrete group is independent of g in a range, provided that $n = 1$ or $n > 2$. For $n = 1$, this becomes homological stability of surface diffeomorphism groups with discrete topology which was first conjectured by Morita. The stable homology is isomorphic to the homology of a certain infinite loop space related to the Haefliger's classifying space of foliations. One geometric consequence of this description of the stable homology is a splitting theorem that implies certain classes called generalized Mumford-Morita-Miller classes can be detected on flat $(\#^g S^n \times S^n)$-bundles for $g \gg 0$. (Received August 29, 2014)

1106-55-528 **Joel Foisy**, **Hugh N Howards** and **Natalie R Rich*** (nrrich@alumni.unca.edu), University of Nebraska - Lincoln, Department of Mathematics, 203 Avery Hall 880130, Lincoln, NE 68588. *Intrinsic Linking and Knotting in Directed Graphs.*

We extend the notion of intrinsic linking and knotting to directed graphs. We give methods of constructing intrinsically linked directed graphs, as well as directed graphs with arbitrarily large numbers of edges that are not intrinsically linked. We give a simple construction that takes a graph G and doubles it to get a directed graph Γ with twice as many edges as G, proving that it gives an intrinsically linked directed graph if and only if G is intrinsically linked. One corollary is that J_6, the complete directed graph on six vertices (with 30 directed edges), is intrinsically linked. (Received September 01, 2014)

1106-55-603 **Julia E Bergner*** (jbergner@ucr.edu). *Models for equivariant $(\infty, 1)$-categories.*

Recent results of Stephan give conditions under which a cofibrantly generated model category has an equivariant analogue, where the objects have a group action and weak equivalences and fibrations are defined via fixed point objects. We apply his results to several models for $(\infty, 1)$-categories. For discrete groups, all of these models satisfy the required conditions. Applying a result of Bohmann-Mazur-Osorno-Ozornova-Ponto-Yarnall, we get an extension to the equivariant setting of the Quillen equivalences between their respective model categories. For actions of simplicial groups or compact Lie groups, we need to restrict to those models which have the additional structure of a simplicial or topological model category, respectively. (Received September 03, 2014)

1106-55-958 **Diego A Vela*** (dav2@rice.edu), 6100 Main Street, MS-136, Houston, TX 77005. *Infection By A String Link.*

Knots and links play an important role in 3-manifolds and the equiva- lence relation of concordance of knots and links plays an important role in 4-manifolds. We will discuss our work that shows, loosely speaking, that we cannot hope to classify knot concordance without simultaneously classifying link concordance for links of an arbitrary number of components. Cochran- Friedl-Teichner considered generalized satellite operations R: SL(m) $\rightarrow$ AS, called “infection by a string link”, where SL(m) is the set of concordance classes of m-component links, AS is the set of concordance classes of al- gebraically slice knots, and the “pattern” knot R is some ribbon knot R. They proved that, for any such knot K there exists some R, m and L such that R(L)=K. We show that one cannot put an upper bound on m. Links arise from knots since the spine of a Seifert surface is essentially a link. Our obstructions are related to the Alexander polynomials of such links. (Received September 09, 2014)

1106-55-1059 **Ulrike Tillmann*** (tillmann@maths.ox.ac.uk). *Commutative K-Theory.*

Vector bundles over a compact manifold can be defined via transition functions to a linear group. Often one imposes conditions on this structure group. For example for real vector bundles one may ask that all transition functions lie in the special orthogonal group to encode orientability. Commutative K-theory arises when we impose the condition that the transition functions commute with each other whenever they are simultaneously defined. We will introduce commutative K-theory and some natural variants of it, and will show that they give rise to new generalised cohomology theories.

This is joint work with Adem, Gomez and Lind building on previous work by Adem, F. Cohen, and Gomez. (Received September 10, 2014)

1106-55-1247 **Seong Ju Kim**, **Ryan Stees*** (steesrc@dukes.jmu.edu) and **Laura Taalman**. *Spiral Knot Determinants.*

Spiral knots are a generalization of the well-known class of torus knots. We have completely characterized the determinants of spiral knots with 2, 3, and 4 strands both in terms of a Jordan Canonical Form calculation using a new periodic crossing matrix method and in terms of recurrence relations that hint at a pattern that could hold for general spiral knots. (Received September 11, 2014)

1106-55-1269 **Agnes Beaudry*** (beaudry@math.uchicago.edu), 5436 S Ridgewood CT APT 3, Chicago, IL 60615. *Cohomology : A Mirror of Homotopy.*

The philosophy of chromatic homotopy theory is that the stable homotopy groups of the sphere S can be re-assembled from the homotopy groups of a family of spectra $L_{K(n)}S$. Roughly, $L_{K(n)}S$ is the n-th chromatic layer of S. There are spectral sequences whose input is the cohomology of a group, the Morava Stabilizer group, and whose output is the homotopy of the n-th chromatic layer. In this talk, I will illustrate of how some of these spectral sequences mirror the homotopy groups of $L_{K(n)}S$ and of S. (Received September 11, 2014)

1106-55-1557 **William G. Dwyer** and **Kathryn Hess*** (kathryn.hess@epfl.ch), EPFL SB MATHGEOM, Station 8, 1015 Lausanne, Switzerland. *Spaces of long embeddings and right-angled Artin operads.*

(Joint work with Bill Dwyer) Generalizing the notion of a right-angled Artin group or monoid, we define a right-angled Artin operad to be the quotient of a free operad by the operadic ideal generated by a set of "commutator" relations of the form $(x; y, ..., y) \sim (y; x, ..., x) \cdot \tau$, where x and y are generators, and τ is an appropriate permutation. The Boardman-Vogt tensor product of two free operads is an important example of a right-angled Artin operad.

Explicit resolutions of a right-angled Artin operad as a bimodule or an infinitesimal bimodule over itself are essential tools in our identification of the space of long embeddings of $\mathbb{R}^m$ into $\mathbb{R}^n$ as the $(m+1)$-fold loop space on the derived mapping space of operad maps from the little m-balls operad to the little n-balls operad. I will sketch the proof of this identification briefly, emphasizing the role of right-angled Artin operads. (Received September 14, 2014)

1106-55-1707 **Michael J. Hopkins*** (mjh@math.harvard.edu), Department of Mathematics, Harvard University, 1 Oxford St., Cambridge, MA 02138. *Algebraic topology: new and old directions.*

Algebraic topology has occupied many different places in the landscape of mathematics. This talk will survey some of these, and the often surprising twists and turns that brought the subject to them. (Received September 15, 2014)

1106-55-1715 **Michael J. Hopkins*** (mjh@math.harvard.edu), Department of Mathematics, Harvard University, 1 Oxford St., Cambridge, MA 02138. *The Kervaire invariant problem.*

The first lecture of this series described some of the many roles algebraic topology has played in mathematics. Threaded through much of this history is the "Kervaire invariant" problem. This lecture will be about the different formulations of this problem and its relatively recent solution by Mike Hill, myself, and Doug Ravenel. (Received September 15, 2014)

1106-55-1780 **Gabriel Valenzuela*** (gvalenzuela@wesleyan.edu), Mathematics and Computer Science Department, Exley Science Center, 265 Church Street, Middletown, CT 06459. *How to Do Homological Algebra with Complete Modules.*

Let R be a finite-dimensional regular local ring with maximal ideal $\mathfrak{m}$. The category of $\mathfrak{m}$-complete R-modules is not abelian, but it can be enlarged to an abelian category of so-called L-complete modules. This category is an abelian subcategory of the full category of R-modules, but it is not usually a Grothendieck category. It is well known that a Grothendieck category always has a derived category, however, this is much more delicate for arbitrary abelian categories.

In this talk, we will show that the derived category of the L-complete modules exists, and that it is in fact equivalent to a certain Bousfield localization of the full derived category of R. L-complete modules should be dual to $\mathfrak{m}$-torsion modules, which do form a Grothendieck category. We will make this precise by showing that although these two abelian categories are clearly not equivalent, they are derived equivalent. (Received September 15, 2014)

1106-55-1792 **Christin Bibby*** (bibby@uoregon.edu). *Abelian Arrangements.*

An abelian arrangement is a finite set of codimension one abelian subvarieties in a complex abelian variety. We are interested in the topology of the complement of an arrangement. If the arrangement is unimodular, we provide a combinatorial presentation for a differential graded algebra that is a model for the complement, in the sense of rational homotopy theory. Moreover, this DGA has a bi-grading that allows us to compute the mixed Hodge numbers. If the arrangement is also supersolvable, then this model is a Koszul algebra. In this case, studying its quadratic dual gives a combinatorial description of the $\mathbb{Q}$-nilpotent completion of the fundamental group and the minimal model of the complement of the arrangement. (Received September 15, 2014)

1106-55-1972 **Kerry M. Luse*** (lusek@trinitydc.edu) and **Mark E. Kidwell** (mek@usna.edu). *Predicting the number and type of twist sits in a rational knot or link.* Preliminary report.

A rational knot or link can be put into a standard alternating format which has horizontal and vertical twist sites (double helices). The number and type of these twist sites are determined by terms of next-to-highest z-degree in Kauffman's regular isotopy invariant $\Lambda(a, z)$. In particular, for a knot or link with c crossings, the coefficient of the z^{c-2} term is equal to the number of twist sites in its standard diagram. Furthermore, the coefficients of the $a^{-2}z^{c-2}$ and a^2z^{c-2} count the number of left-turning and right-turning twist sites, respectively. (Received September 15, 2014)

1106-55-2045 **Vigleik Angeltveit** and **Teena Gerhardt*** (teena@math.msu.edu). *Computations in Algebraic K-Theory.*

Abstract: In general algebraic K-theory groups are difficult to compute, but in recent years methods in equivariant stable homotopy theory have made some computations more accessible. Using these methods to compute the algebraic K-theory of pointed monoid algebras is particularly interesting, as the full power of equivariant homotopy groups is used. I will recall some successes of these methods and describe how equivariant techniques contribute to a new strategy for answering a classical computational question. In particular, I will discuss a new approach to computing the algebraic K-theory of the group ring $\mathbb{Z}[C_2]$. (Received September 15, 2014)

1106-55-2238 **Michael J. Hopkins*** (mjh@math.harvard.edu), Department of Mathematics, Harvard University, 1 Oxford St., Cambridge, MA 02138. *Chern-Weil theory and abstract homotopy theory.*

As was so beautifully depicted by Hermann Weyl in "The Classical Groups", many of the fundamental structures of geometry can be discovered as the invariants of symmetries. This talk will explore one collection of these, the Chern-Weil invariants, and how carefully expressing the way in which they are "invariants" naturally leads to the framework of abstract homotopy theory. (Received September 16, 2014)

1106-55-2246 **Christopher L Rogers*** (rogersc@uni-greifswald.de), Institut für Mathematik und Informatik, Universität Greifswald, Walther-Rathenau-Straße 47, D-17487 Greifswald, Germany. *Homotopy transfer is a simple consequence of the Goldman-Millson Theorem.*

Let $(A, d_A, \{\mu_k\})$ be an A_∞-algebra over a field of characteristic 0, (V, d_V) a cochain complex, and $\phi\colon V \to A$ a chain map which induces an isomorphism on cohomology. The Homotopy Transfer Theorem says that there exists an A_∞ structure on V, and a A_∞-quasi-isomorphism $\Phi\colon (V, d_V, \{\nu_k\}) \to (A, d_A, \{\mu_k\})$ lifting the chain map ϕ. Moreover, the A_∞-structure on V and lift of ϕ is unique up to homotopy, in the strongest possible sense. We show that these facts follow simply and directly from a homotopical analog of the Goldman-Millson Theorem, a classical result from deformation theory. This result is a small advertisement for recent joint work (arXiv:1407.6735) with V. Dolgushev on the homotopy theory of homotopy algebras (See also arXiv:1406.1751.) (Received September 16, 2014)

1106-55-2273 **John D. Foley*** (foley@math.ku.dk). *Recognizing nullhomotopic maps between the classifying spaces of Kac-Moody groups.*

Among the first applications of the successful proof of the Sullivan conjecture where characterizations of nullhomotopic maps between the classifying spaces of compact Lie groups. This talk considers the problem of recognizing when maps between the classifying spaces of Kac-Moody groups—which generalize compact Lie groups—are nullhomotopic. We show that many known characterizations of nullhomotopic maps from the Lie setting extend to the Kac-Moody setting after completing at some prime p. However, assembling this p-local information with the arithmetic fiber square exposes new subtleties for our integral recognition problem. Nevertheless, we provide a solution to our problem for a set of Kac-Moody groups that includes elements of all ranks. Nullhomotopic maps between the classifying spaces of groups in this set can be detected by restricting to the maximal torus. (Received September 16, 2014)

1106-55-2330 **Marian F Anton** and **Kim-Vui H Duong*** (k.duong@my.ccsu.edu). *Index Theory in a Paschian Geometry.* Preliminary report.

We investigate an index theory in a geometry which is subject only to the incidence and order axioms. In particular, we give some applications to coverage problems for planar regions bounded by simple closed polygons and inquire about their generalizations. (Received September 16, 2014)

1106-55-2718 **Ayman Mohammad Almomany*** (almom1am@cmich.edu), Department of Mathmatics, Pearce 214, Mount Pleasant, MI 48858, and **Brad Safnuk**. *Intersection numbers on moduli spaces of curves through topological recursion.*

To explore relationships between the plane algebraic curve and intersection numbers of tatolgical classes on moduli spaces of curves. The link is provided by Eynard and orentin's theory of topological recursion, which associates to any plane algebraic curve an infinite family of invariants. Due to work of Eynard, it is expected that these invariants are closely related to intersection numbers on moduli spaces of curves, but the explicit calculation has not yet been carried out. A particular focus will be coming up with an analogue of the so –called ELSV formula, which relates Hurwitz number to linear Hodge integrals, and has been an important source for many ground breaking results (Received September 16, 2014)

1106-55-2823 **Jeffrey D. Carlson*** (jeffrey.carlson@tufts.edu), Department of Mathematics, Tufts University, 503 Boston Ave., Medford, MA 02155. *Circle subgroups of compact Lie groups.*

Let G be a compact, connected Lie group and S a circle subgroup; then S naturally acts on the left on the quotient G/S. Given a de Rham cohomology class $[\omega]$ on G/S, there sometimes exists an "S-equivariant extension," which allows one to localize the integral of ω over an S-invariant subset of G/S to a subset of the fixed point set. While explicit expressions for these extensions can be difficult to find, whether such an extension exists for all cohomology classes (a condition called "equivariant formality") can be determined solely in terms of the dimension of the cohomology ring of G/S and the number of components (1 or 2) of the normalizer N of S.

This reduction turns equivariant formality for this class of spaces into a geometric problem about an embedding of a circle in a group. The cohomology ring of G/S has a simple description already outlined by Jean Leray in 1946, and the action of the normalizer N on S either is trivial or induces a reflection. In this talk, I will describe this ring structure and tell which circles are reflected. The most interesting case is that of the exceptional group E_6, where we determine a reflected circle must be conjugate into a Spin(8) subgroup. (Received September 16, 2014)

57 ► Manifolds and cell complexes

1106-57-14 **Ian Agol*** (ianagol@berkeley.edu), University of California, Berkeley, 970 Evans Hall 3840, Berkeley, CA 94720-3840. *Title to be announced.* Preliminary report.

We'll discuss recent results regarding 3-manifolds and their fundamental groups. More specifically, we'll discuss finite-sheeted covers of compact 3-manifolds admitting various properties, and how these are interpreted in terms of properties of the fundamental group, such as residual finiteness and linearity. We'll survey some of the ingredients in geometric group theory used to resolve these questions, in particular CAT(0) cube complexes and hyperbolic groups, and the progress made in their study by Dani Wise and his collaborators. (Received April 28, 2014)

1106-57-231 **Christian R Millichap*** (christian.millichap@gmail.com). *Geometrically Similar Hyperbolic Pretzel Knots.*

Given a hyperbolic 3-manifold M, there are a number of geometric invariants of interest. Two such invariants are the volume of M and the length spectrum of M, that is, the set of all lengths of closed geodesics in M counted with multiplicities. It is natural to ask how often can hyperbolic manifolds have the same volume, the same length spectrum, or perhaps even both. In this talk, we shall construct large families of hyperbolic pretzel knots whose complements have both the same volume and the same initial length spectrum, but are pairwise incommensurable, i.e., they do not share a common finite sheeted cover. In particular, we shall show that the number of hyperbolic knot complements with the same volume and initial length spectrum grows at least factorially fast with the volume and the number of twist regions. This proof relies on Ruberman's work on mutations along Conway spheres in least area form that preserve volume, and expanding this analysis to see when these Conway spheres could intersect short geodesics in a hyperbolic 3-manifold. (Received August 13, 2014)

1106-57-275 **Ryan Blair**, **Marion Campisi*** (mcampisi@stanford.edu), **Jesse Johnson**, **Scott Taylor** and **Maggy Tomova**. *Exceptional and cosmetic surgeries on knots.* Preliminary report.

We show that the bridge distance of a knot determines a lower bound on the genus of essential surfaces and Heegaard surfaces in the manifolds that result from non-trivial Dehn surgeries on the knot. In particular, knots with high bridge distance do not admit non-trivial non-hyperbolic surgeries or non-trivial cosmetic surgeries. We further show that if a knot has bridge distance at least 3 then its bridge number is bounded above by a function of Seifert genus, or indeed by the genus of (almost) any essential surface or Heegaard surface in the surgered manifold. (Received August 18, 2014)

1106-57-276 **Scott Van Thuong*** (sthuong@pittstate.edu), 1701 S Broadway, Pittsburg, KS 66762. *All 4-dimensional infra-solvmanifolds are boundaries.*

Infra-solvmanifolds are a certain class of aspherical manifolds which generalize both flat manifolds and almost flat manifolds (i.e., infra-nilmanifolds). Every 4-dimensional infra-solvmanifold is diffeomorphic to a geometric 4-manifold with geometry of solvable Lie type.

There were questions about whether or not all 4-dimensional infra-solvmanifolds bound. We answer this affirmatively. On each infra-solvmanifold M admitting $\mathrm{Nil}^3 \times \mathbb{R}$,$\mathrm{Nil}^4$, $\mathrm{Sol}^3 \times \mathbb{R}$, or Sol_1^4 geometry, an isometric involution with 2-dimensional fixed set is constructed. The Stiefel-Whitney number $\omega_1^4(M)$ vanishes by a result of R.E. Stong and from this it follows that all Stiefel-Whitney numbers vanish. (Received August 18, 2014)

1106-57-278 **Patricia Cahn*** (pcahn@sas.upenn.edu) and **Vladimir Chernov**. *The Classification of V-Transverse Knots and Loose Legendrians.*

We classify knots in a 3-manifold M that are transverse to a nowhere zero vector field V, up to the corresponding isotopy relation. When V is the co-orienting vector field of a contact structure, these knots are the same as pseudo-Legendrian knots, which were introduced by Benedetti and Petronio. We show that two loose Legendrian knots with the same overtwisted disk in their complement are Legendrian isotopic if and only if they are pseudo-Legendrian isotopic, generalizing results of Dymara and Ding-Geiges. V-transverse knots are naturally framed. We show that each framed isotopy class contains infinitely many V-transverse isotopy classes whose elements are pairwise distinct up to V-transverse homotopy, provided that one of the following conditions holds: V is a co-orienting vector field of a tight contact structure; the manifold M is irreducible and atoroidal; or, the Euler class of a 2-dimensional bundle orthogonal to V is a torsion class. We also give examples of infinite sets of distinct V-transverse isotopy classes whose representatives are all V-transverse homotopic and framed isotopic. If time permits, we will discuss applications to the coarse classification of Legendrian knots, which is joint work with Bulent Tosun. (Received August 18, 2014)

1106-57-369 **Hans U. Boden** and **Cynthia L. Curtis*** (ccurtis@tcnj.edu), Department of Mathematics and Statistics, The College of New Jersey, Ewing, NJ 07746. *The $SL(2,\mathbb{C})$ Casson knot invariant and the $\widehat{A}$-polynomial.*

We present a definition of the $\mathrm{SL}(2,\mathbb{C})$ Casson invariant for knots K in integral homology 3-spheres. We establish a relationship between $\mathrm{SL}(2,\mathbb{C})$ Casson knot invariant and the m-degree of the $\widehat{A}$-polynomial of K. We present an example of a nontrivial knot K in S^3 with $\widehat{A}_K(m,\ell)$ equal to that of the unknot, and we conclude from this that the $\mathrm{SL}(2,\mathbb{C})$ Casson knot invariant does not detect the unknot. (Received August 25, 2014)

1106-57-384 **Dennis M Roseman*** (dennis.roseman@gmail.com), 2611 East Court Street, Iowa city, IA 52245. *Bulky Knots.*

For classical knots and links in R^3 a general planar projection has only crossing points. However a knotted or linked surface $M^2 \subseteq R^4$ may have triple points when projected to R^3. Links such that all projections must have triple points are called bulky links. In the orientable case, a bulky link is a non-psuedo-ribbon link. For surface links M^2 with three or more components we define a new invariant that can detect bulky links. Proof is by showing invariance under higher dimensional knot moves.

For higher dimensional links $M^n \subseteq R^{n+2}$ we extend definition of bulky links and discuss an extension of our invariant. (Received August 26, 2014)

1106-57-434 **Bo-hyun Kwon***, 2312 Frisco Way, Edmond, OK 73012. *On the Jones polynomial of 2n-plat presentations of knots.* Preliminary report.

In this paper, a method is given to calculate the Jones polynomial of the 6-plat presentations of knots by using a representation of the braid group $\mathbb{B}_6$ into a group of 5×5 matrices. We also can calculate the Jones polynomial of the $2n$-plat presentations of knots by generalizing the method for the 6-plat presentations of knots. Also, it helps us detect 3-bridge knots in 3-plat presentations. (Received August 28, 2014)

1106-57-437 **Nguyen D Duong*** (ndduong@crimson.ua.edu), 424 7th Ave Ne, Apt C6, Tuscaloosa, AL 35404, and **Lawrence P Roberts**. *Planar algebra structure in bordered Khovanov homology.* Preliminary report.

I'll discuss work-in-progress with Lawrence Roberts toward constructing a planar algebra structure in bordered Khovanov homology. We define an invariant (type DA structure) for tangles subordinate to disc configurations. This type DA structure will induce a morphism from the planar algebra of tangle diagrams (defined by Dror Bar-Natan) to the category of A_∞ modules. (Received August 28, 2014)

1106-57-798 **Jennifer Hom**, **Cagri Karakurt** and **Tye Lidman*** (tlid@math.utexas.edu). *Homology three-spheres and surgery obstructions.*

We construct infinitely many prime homology spheres that cannot be realized as Dehn surgery on a knot in S^3. (Received September 06, 2014)

1106-57-865 **John Etnyre*** (etnyre@math.gatech.edu), **David Shea Vela-Vick** and **Rumen Zarev**. *Sutured Floer homology and invariants of Legendrian and transverse knots.*

Using contact-geometric techniques and sutured Floer homology, we present an alternate formulation of the minus and plus version of knot Floer homology. We further show how natural constructions in the realm of contact geometry give rise to much of the formal structure relating the various versions of Heegaard Floer homology. In addition we discuss how to define invariants of Legendrian and transverse knots from this perspective that recover the Legendrian/transverse invariant defined by Lisca, Ozsvath, Stipsicz, and Szabo despite a strikingly dissimilar definition. (Received September 08, 2014)

1106-57-957 **Elena Pavelescu*** (elena.pavelescu@okstate.edu), Oklahoma State University, MSCS 528, Stillwater, OK 74078, and **Ramin Naimi** (rnaimi@oxy.edu), Occidental College, 1600 Campus Road, Los Angeles, CA 90041. *Oriented matroids and straight-edge embeddings of graphs.*

Matroid theory is an abstract theory of dependence introduced by Whitney in 1935. It is a natural generalization of linear (in)dependence. Oriented matroids can be thought of as combinatorial abstractions of point configurations over the reals. To every linear (straight-edge) embedding of a graph one can associate an oriented matroid, and the oriented matroid captures enough information to determine which pairs of disjoint cycles in the embedded graph are linked. In this talk, we will introduce the basics of oriented matroids. Then we show that any linear embedding of K_9, the complete graph on nine vertices, contains a non-split link with three components. (Received September 09, 2014)

1106-57-1092 **Oliver Dasbach*** (kasten@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803, and **Mustafa Hajij**. *Sums of knots, and the colored Jones polynomial.* Preliminary report.

A natural operation on oriented knots is given by the connected sum. Polynomial knot invariants like the Alexander polynomial or the Jones polynomial behave nicely under this operation. We will discuss other sums for knots, and the implications for the colored Jones polynomial. (Received September 10, 2014)

1106-57-1096 **Jennifer Hom*** (hom@math.columbia.edu). *An infinite rank summand of topologically slice knots.* Preliminary report.

Let T denote the subgroup of the smooth knot concordance group generated by topologically slice knots. Endo showed that T contains an infinite rank subgroup, and Livingston and Manolescu-Owens showed that T contains a summand of rank three. We show that in fact T contains an infinite rank summand. The proof relies on the knot Floer homology package of Ozsvath-Szabo and the concordance invariant epsilon. (Received September 10, 2014)

1106-57-1106 **Ina Petkova*** (ina@rice.edu) and **Vera Vertesi**. *Combinatorial tangle Floer homology.*

We extend the functoriality in Heegaard Floer homology by defining a Heegaard Floer invariant for tangles which satisfies a nice gluing formula. We will discuss the construction of this combinatorial invariant for tangles in S^3, D^3, and $I \times S^2$. The special case of S^3 gives back a stabilized version of knot Floer homology. No prior knowledge of Heegaard Floer homology will be assumed for this talk. (Received September 10, 2014)

1106-57-1115 **John A Baldwin** and **David Shea Vela-Vick*** (shea@math.lsu.edu). *A refinement of the Ozsváth-Szabó contact invariant.*

We present a refinement of the Ozsvath-Szabo contact invariant in Heegaard Floer theory. This invariant, denoted t, takes values in $\mathbb{Z}_{>0} \cup \{\infty\}$, and extends the usual contact invariant in the sense that if $c(Y, \xi) \neq 0$, then $t = \infty$. We further show that if (Y, ξ) is overtwisted, then $t(Y, \xi) = 1$, reflecting the usual vanishing of the Ozsvath-Szabo invariant for such contact structures. In this talk, we will focus on the construction of t and discuss some of its basic properties. (Received September 10, 2014)

1106-57-1126 **Moshe Cohen*** (mcohen@tx.technion.ac.il). *Invariants of random Chebyshev billiard table diagrams.* Preliminary report.

Koseleff and Pecker showed that every knot can be parametrized as a generalized harmonic curve using Chebyshev polynomials and a phase shift. These have diagrams that appear as nice trajectories on billiard tables. We present a model for random knotting using these diagrams.

We study data obtained from polynomial invariants of these random knots. We compute the Alexander polynomials from grid graphs based on previous work with Dasbach and Russell. We compute the Jones polynomials for 2- and 3-bridge knots based on previous work by the author using these diagrams.

Supported in part by the funding from the European Research Council under the European Union's Seventh Framework Programme, Grant FP7-ICT-318493-STREP. (Received September 10, 2014)

1106-57-1164 **John A Baldwin*** (john.baldwin@bc.edu), **Matt Hedden** and **Andrew Lobb**. *On the functoriality of Khovanov-Floer theories.* Preliminary report.

There has been a lot of interest in recent years in connections between Khovanov homology and Floer theory. These connections usually come in the form of spectral sequences, with E_2 page the Khovanov homology of a link and converging to the relevant Floer theory. Important examples include Ozsvath-Szabo's spectral sequence in Heegaard Floer homology and Kronheimer-Mrowka's spectral sequence in singular instanton Floer homology. In particular, the latter was used to prove that Khovanov homology detects the unknot. A natural question is whether these constructions are functorial? That is, are the intermediate pages of these spectral sequences link invariants, and do link cobordisms induce well-defined maps on these pages? We answer these questions in the affirmative, as part of a much more general framework. At the end, we will describe how this framework might be used to define a host of new knot and cobordism invariants. This is joint work with Matt Hedden and Andrew Lobb. (Received September 11, 2014)

1106-57-1228 **Katherine Vance*** (kvance@rice.edu). *Tau invariants for balanced spatial graphs.* Preliminary report.

Recently Harvey and O'Donnol defined a combinatorial Heegaard Floer homology theory $\widehat{HFG}$ for spatial graphs. Their theory is relatively bigraded, with an integer-valued Maslov grading and a relative Alexander grading, which takes values in the first homology of the spatial graph exterior. We define a $\mathbb{Z}$-filtered chain complex $\widehat{CG}$ for balanced spatial graphs whose associated graded chain complex has homology determined by $\widehat{HFG}$. We use this to show that there is a well-defined τ invariant for balanced spatial graphs generalizing the τ knot concordance homomorphism defined by Ozsvath-Szabo and Rasmussen. One step in showing there is a filtration is to lift the relative Alexander grading to an absolute grading. (Received September 11, 2014)

1106-57-1238 **David Krcatovich*** (david-k@rice.edu), Rice University, Math Department – MS 136, 6100 Main St, Houston, TX 77005. *The reduced knot Floer complex.*

In this talk we will introduce a reduced form of the knot Floer complex associated to a knot in S^3. We will see how it simplifies computations for connected sums of knots, and can be used to compute smooth concordance invariants. As an application, we will see how the reduced complex lends itself to a simple proof of the fact that a knot in S^3 which admits an L-space surgery must be prime. (Received September 11, 2014)

1106-57-1270 **Mohamed Ait Nouh*** (manouh@utep.edu), 500 University Avenue, El Paso, TX 79968. *THE MINIMAL GENUS PROBLEM IN* $\mathbb{CP}^2\#\mathbb{CP}^2$.

T. Lawson conjectured that the minimal genus of $(m,n) \in H_2(\mathbb{CP}^2\#\mathbb{CP}^2)$ is given by $\binom{|m|-1}{2} + \binom{|n|-1}{2}$ -this is the genus realized by the connected sum of algebraic curves in each factor. In this talk, we give two infinite families of counterexamples and finite positive examples to this conjecture. (Received September 11, 2014)

1106-57-1273 **Cameron McA. Gordon***, gordon@math.utexas.edu, and **Tye Lidman**, tlid@math.utexas.edu. *Left-orderability and cyclic branched covers.*

It is conceivable that for a rational homology 3-sphere M, the following are equivalent: (1) $\pi_1(M)$ is left-orderable, (2) M admits a co-orientable taut foliation, and (3) M is not a Heegaard Floer L-space. We will discuss these properties in the case where M is a cyclic branched cover of a knot in S^3. (Received September 11, 2014)

1106-57-1347 **Meredith G Anderson*** (mand1269@nmsu.edu), Department of Mathematical Sciences, 1291 Frenger Mall, MSC 3MB / Science Hall 236, Las Cruces, NM 88003. *Character Varieties of Dehn Fillings of a 3-component Link.* Preliminary report.

Kenneth Baker, Jesse Johnson and Elizabeth Klodginski proved that every tunnel number one once-punctured torus bundle is the $r/1$-Dehn filling of a boundary component of the Whitehead link exterior, for some integer r. Subsequently, Baker and Kathleen Petersen calculated the character varieties of these manifolds using the bundle description. The canonical component of a character variety for one of these manifolds is a complex curve. Using the ideas in these papers, I examine an infinite family of 3-manifolds which are bundles over the circle with fiber a twice-punctured torus. These manifolds can be obtained as the Dehn filling of a boundary component of the exterior of a three component link, where two of the components form the Whitehead link. I then find descriptions of the character varieties for these manifolds, working from fundamental group presentations with three generators and two relations. The canonical component of a character variety of one of these examples turns out to be a complex surface which is the product of an affine line with a plane curve. (Received September 12, 2014)

1106-57-1402 **Taylor E. Martin***, taylor.martin@shsu.edu. *Structure in Lower Order Quotients of the n-Solvable Filtration.*

The n-solvable filtration of the link concordance group, defined by Cochran, Orr, and Teichner in the late 90's, gives structure to the smooth knot and link concordance groups. Much is known about the n-solvable filtration of the knot concordance group for small n. For example, a knot is 0-solvable if and only if it has Arf invariant zero. Moreover, a knot is 0.5-solvable precisely when it's Seifert matrix looks like that of a slice knot, called algebraically slice. Comparatively little is known for links. In this talk, we will mention a classification of 0-solvable links, progress towards understanding 0.5-solvable links, and work towards understanding the structure of lower order quotients of the n-solvable filtration. (Received September 12, 2014)

1106-57-1456 **Jason Thomson La Corte*** (jlacorte@uwm.edu), University of Wisconsin-Milwaukee, Department of Mathematical Sciences, P.O. Box 413, Milwaukee, WI 53201-0413. *Approximating optimal curvature-constrained paths in nonpositively curved square complexes.* Preliminary report.

We demonstrate a numerical method for solving the Dubins problem with free terminal vector in a nonpositively curved square complex, and show how the solutions to this problem model efficient strategies for reconfiguring a robotic system in motion. We first show how the state space of a particular system can be represented as the Davis complex of a right-angled Coxeter group. We then exhibit computer animations that trace paths in the complex and display the corresponding reconfigurations of the system. Finally, given an initial state, initial direction, and desired objective state, we show how to find a practical and efficient reconfiguration strategy by numerically determining the shortest curvature-constrained path in the state space satisfying the given boundary conditions. (Received September 16, 2014)

1106-57-1457 **Kenneth L Baker**, Department of Mathematics, University of Miami, Coral Gables, FL 33146, and **Allison H Moore*** (allison.h.moore@rice.edu), Department of Mathematics, Rice University, Houston, TX 77005. *Montesinos knots, Hopf plumbings, and L-space surgeries.*

Using Hirasawa-Murasugi's classification of fibered Montesinos knots we classify the L-space Montesinos knots, providing further evidence towards a conjecture that L-space knots have no essential Conway spheres. In the process, we classify the fibered Montesinos knots whose open books support the tight contact structure on the three-sphere. We also construct L-space knots with arbitrarily large tunnel number and discuss some questions about essential tangle decompositions and tunnel number of L-space knots. (Received September 13, 2014)

1106-57-1518 **Dorothy Buck** and **Danielle O'Donnol*** (odonnol@okstate.edu). *Unknotting number one theta-curves and DNA replication.* Preliminary report.

A theta-curve is an embedded theta-graph. We are investigating unknotting number one theta-curves. This has immediate applications to questions about knotting that occurs during DNA replication. I will discuss our recent results on unknotting number one theta-curves and the unknotting numbers for prime theta-curves up to seven crossings. (Received September 13, 2014)

1106-57-1751 **Susan M. Abernathy*** (susan.abernathy@angelo.edu) and **Patrick M. Gilmer** (gilmer@math.lsu.edu). *Even and odd Kauffman bracket ideals for genus-1 tangles.* Preliminary report.

A genus-1 tangle is a 1-manifold with two boundary components properly embedded in the solid torus. A genus-1 tangle $\mathcal{G}$ embeds in a link L if we can complete $\mathcal{G}$ to L via a 1-manifold in the complement of the solid torus containing $\mathcal{G}$. A natural question to ask is: given a tangle $\mathcal{G}$ and a link L, how can we tell if $\mathcal{G}$ embeds in L? We obtain an obstruction to tangle embedding by defining even and odd versions of the Kauffman bracket ideal. We also give an example of a genus-1 tangle with trivial Kauffman bracket ideal which has non-trivial even and odd Kauffman bracket ideals. (Received September 15, 2014)

1106-57-1766 **Grigori Avramidi**, **Michael W. Davis**, **Boris Okun** and **Kevin Schreve*** (kschreve@uwm.edu). *Action Dimension of Right-Angled Artin Groups.*

The action dimension of a discrete group Γ is the smallest dimension of a contractible manifold which admits a proper action of Γ. Associated to any flag complex L there is a right-angled Artin group, A_L. We compute the action dimension of A_L for many L. Our calculations come close to confirming the conjecture that if an L^2-Betti number of A_L in degree l is nonzero, then the action dimension of A_L is $\geq 2l$. (Received September 15, 2014)

1106-57-1799 **Sarah R McGahan*** (srmcg@mail.fresnostate.edu) and **Andrew V de la Pena**.
Alexander- and Markov-type theorems for virtual singular links. Preliminary report.

A classical braid is a set of n strings passing between two horizontal bars. These strings may interact with one another but must always travel in the downward direction. If the two horizontal bars are brought together and each pair of string ends are glued together in order, the resulting structure will be a knot or a link which we call the closure of the braid. J.W. Alexander showed that any oriented classical link can be represented as the closure of a braid. In addition, it is well-known that two braids have isotopic closures if and only if they are related by braid isotopy and a finite series of the so-called Markov's moves. These two properties of braids are known as the Alexander and Markov Theorems. Analogous theorems have been proved for the set of virtual links as well as for the set of singular links.

In this talk we first introduce the virtual singular braid monoid via generators and relations. We then prove Alexander and Markov-type theorems for virtual singular links. (Received September 15, 2014)

1106-57-1807 **Darren M Garbuz*** (dgarbuz@slu.edu). *Decomposing Dehn Twists in Terms of Lickorish Generators.*

Let M be a closed orientable 3-manifold with Heegaard splitting $M = V_1 \cup_f V_2$. Suppose that we are given a diagram of the Heegaard splitting that shows us where the meridian curves of ∂V_1 are mapped to by f. We discuss the problem of finding a formula for f in the case that $M = S^1 \times S^1 \times S^1$. (Received September 15, 2014)

1106-57-1934 **Cody Armond*** (cody-armond@uiowa.edu), **Nathan Druivenga** and **Thomas Kindred**. *Heegaard diagrams corresponding to Turaev surfaces.*

Turaev surfaces are special surfaces constructed from link diagrams which the link projects to in an alternating fashion. We describe a correspondence between Turaev surfaces of link diagrams and special Heegaard diagrams adapted to the links. (Received September 15, 2014)

1106-57-2196 **Adam Giambrone*** (giambroneaj@alma.edu). *Volume Bounds for Families of A-Adequate Link Diagrams.*

In this talk, we will examine how the structure of certain families of A-adequate link diagrams can be used to produce bounds for the hyperbolic volume of the link complement. These volume bounds can be expressed in terms of two diagrammatic quantities: a count of the number of twist regions in the link diagram and a count of the number of certain alternating tangles in the link diagram. Furthermore, in many cases, these bounds can also be expressed in terms of a single stable coefficient of the colored Jones polynomial. (Received September 16, 2014)

1106-57-2386 **Michael A Abel*** (maabel@vcu.edu) and **Matt Hogancamp**. *An algebraic construction of colored HOMFLY-PT homology.* Preliminary report.

We construct complexes of Soergel bimodules which categorify the Young idempotents corresponding to one-column partitions. Using these categorical idempotents, we construct a triply graded link homology theory which categorifies the HOMFLY-PT polynomial colored by one-column partitions. This link homology theory specializes to Khovanov-Rozansky homology in the uncolored case. (Received September 16, 2014)

1106-57-2406 **Katherine L. Paullin*** (kpaullin@slu.edu). *Spun Almost Normal Form.* Preliminary report.

Many of a 3-manifold's properties are determined by the surfaces they contain. In a triangulated 3-manifold, Haken and Kneser showed that we could put any incompressible surface in normal form. Rubinstein and Stocking later showed we could extend those techniques to put any strongly irreducible surface into almost normal form. More recently, Walsh has shown that in an ideal triangulation of a hyperbolic manifold many surfaces can be spun normalized. In this talk, I will discuss a combinatorial approach to generalize this result of Walsh's to nonhyperbolic manifolds, and explore under what conditions we may be able to show that a surface can be spun almost normalized. (Received September 16, 2014)

1106-57-2781 **Semeon Arthamonov*** (semeon.artamonov@rutgers.edu), 110 Frelinghuysen Rd, Piscataway, NJ 08854, **Andrei Mironov** (mironov@itep.ru), Bolshaya Cheremushkinskaya 25, Moscow, 117218, Russia, **Alexei Morozov** (morozov@itep.ru), Bolshaya Cheremushkinskaya 25, Moscow, 117218, Russia, and **Andrey Morozov** (andrey.morozov@itep.ru), Bolshaya Cheremushkinskaya 25, Moscow, 117218, Russia.
HOMFLY polynomial calculus for links and AENV conjecture.

Recently Aganagic, Ekholm, Ng, and Vafa conjectured a relation between the augmentation variety in the large N limit of the colored HOMFLY and quantum A-polynomials. In this talk I will describe the methods used for direct confirmation of this conjecture for certain links.

It appears that colored knot polynomials possess an internal structure (we call it Z-expansion). Developing ideas of Garoufalidis we show explicitly that for the large families of links the corresponding colored HOMFLY polynomial for symmetric and anti-symmetric representations can be presented as a truncated sum of a certain q-hypergeometric series. The latter allows us to extend the formulas for the arbitrary symmetric representations and study the asymptotic of the colored HOMFLY polynomials for large symmetric representations.

In addition I will say a few words about the extension of Z-expansion beyond the symmetric representations for some simplest examples. Although for generic representation we no longer have truncated q-hypergeometric series we still have some interesting structure beyond the HOMFLY and superpolynomials. In particular, the introduction of the recently developed fourth grading in all existing examples can be presented as an elegant redefinition of the constituents of Z-expansion. (Received September 16, 2014)

58 ► Global analysis, analysis on manifolds

1106-58-450 **Steven Hurder*** (hurder@uic.edu), Department of Mathematics (m/c 249), University of Illinois at Chicago, 851 S. Morgan Street, 322 SEO, Chicago, IL 60607-7045. *Entropy for Y-like matchbox manifolds.*

A matchbox manifold M is a generalized lamination, with leaves of dimension n. That is, M is a foliated connected metric space of dimension n, which is transversally totally disconnected, and the path components components of M define the leaves of a foliation F.

A matchbox manifold M is Y-like, if Y is a finite simplicial complex of dimension n, and for every e > 0, there is a continuous surjection f : M -> Y whose fibers have diameter at most e.

The geometric entropy h(M,F) is defined using the definition of Ghys, Langevin and Walczak for the geometric entropy of foliated spaces, and may be infinite. It is known that h(M,F) is zero if M is homeomorphic to a weak solenoid, in the sense of McCord and Schori.

For the generalized solenoids, such as the Williams solenoids which are Y-like where Y is a branched manifold of dimension n, in this talk we show how the entropy h(M,F) can be calculated in terms of an inverse limit presentation of M by branched manifolds. (Received August 28, 2014)

1106-58-1152 **Abraham D. Smith*** (adsmith@member.ams.org), 422B John Mulcahy Hall, Mathematics Dept, Fordham University, Bronx, NY 10458-5165. *Degeneracy of the Characteristic Variety and Canonical 1-forms on Involutive PDEs.*

The characteristic variety, Ξ, plays an important role in the analysis of the solution space of differential equations and exterior differential ideals, $\mathcal{I} \subset \Omega^\bullet(M)$. In this talk, I'll discuss the linear span of the characteristic variety, what it tells us about the solutions, and how it can be measured via an integrable extension of the original system of differential forms.

The key feature for this study is a canonical 1-form on the PDEs/EDS, reminiscent of the soldering 1-form, that sheds light on the meaning of Guillemin Normal Form and should allow a detailed, geometric classification of PDEs/EDS. (Received September 11, 2014)

1106-58-1265 **Sofya Chepushtanova*** (chepusht@math.colostate.edu), Department of Mathematics, 1874 Campus Delivery, Fort Collins, CO 80523-1874, and **Michael Kirby**. *Sparse Grassmannian Embeddings for Hyperspectral Image Classification.*

We propose a set-to-set pattern recognition approach for capturing the signal variability in hyperspectral imagery using the framework of the Grassmann manifold. Sets of pixels from the same data class characterize the variability of the class information, so we can organize them as abstract points on the Grassmannian, i.e. subspaces represented by orthonormal matrices. There are a variety of metrics which allow us to determine a distance matrix that is used to realize the Grassmannian as an embedding in the Euclidean space in the context of metric spaces. We use the chordal and the geodesic metrics, as well as a pseudometric of our choice. A sparse support vector machine trained in the Euclidean space gives a classification model for the embedded subspaces as well as a subset of selected dimensions of the embedding for subsequent model reduction. We analyze the behaviour of embeddings and compare classification results for different metrics. We observe that we can achieve an isometric embedding of the Grassmann manifold using the chordal metric, and nearly isometric embedding with geodesic distances. It is also observed that non-isometric embeddings generated by using the pseudometric on the Grassmannian in some cases can lead to the best classification results. (Received September 11, 2014)

1106-58-1335 **Christine M Guenther*** (guenther@pacificu.edu), Department of Mathematics & Computer Science, Pacific University, 2043 College Way, Forest Grove, OR 97116. *Updates on the second order renormalization group flow.* Preliminary report.

The second order renormalization group flow $\frac{\partial}{\partial t}g = -2Rc - \frac{\alpha}{2}Rm^2$ arises in quantum field theory, and can be considered as a natural nonlinear perturbation of the Ricci flow (here $\alpha > 0$ is a parameter and $Rm^2_{ij} := R_{iilm}R_j^{ilm}$). In this talk we highlight recent results, including further work on three-dimensional locally homogeneous spaces. (Received September 12, 2014)

1106-58-1650 **Krystyna Kuperberg*** (kuperkm@auburn.edu). *Fixed-point problems from the Scottish Book.*

We will discuss some problems from the Scottish Book related to fixed points:

1) The solution to Problem 110 posed by Stan Ulam, in particular addressing the existence of non-singular dynamical systems with uniformly bounded orbits.

2) The history of Problem 107 asserting that a planar continuum that does not separate the plane has the fixed point property. In spite of many attempts and partial answers, the problem remains open.

3) The Schauder Fixed Point Theorem, formulated by Julius Schauder in Problem 54, its history and the ultimate solution by Robert Cauty. (Received September 14, 2014)

1106-58-1947 **Ismail Kombe*** (ikombe@ticaret.edu.tr), Istanbul Commerce University, Faculty of Science and Letters, Department of Mathematics, Istanbul, Turkey. *Weighted Hardy and Rellich type inequalities on complete Riemannian manifolds.*

I will discuss several weighted Hardy and Rellich type inequalities and their improved versions on complete Riemannian manifolds. (joint work with A. Yener) (Received September 15, 2014)

60 ► Probability theory and stochastic processes

1106-60-7 **Alan Krinik*** (ackrinik@csupomona.edu), California State Polytechnic Univ., Pomona, Department of Math & Stat, Pomona, CA 91768, and **Dmitry,Vladimir V. Kruchinin**. *Finding the probability of all Markov chain sample paths from j to k in n-steps where j,k > 0 that are bounded below by the x-axis and having transitions of size one or two (up or down).*

Using the reflection principle and generating function techniques, we develop formulas for the probability of various ballot box sample paths. We begin by deriving a formula for the probability of all sample paths (having n-steps) that travel from 0 to k (k, a natural number) with allowable transitions of 1, 2, -1 or -2 only and that are restricted to never touch nor cross the horizontal axis after leaving 0. We next determine the probability of all sample paths(again, only having allowable step size of: 1, 2, -1 or -2) that go from j to k (natural numbers) in n-steps without hitting or crossing the x-axis. (Received September 17, 2014)

1106-60-65 **Hao Wu*** (wu_proba@math.mit.edu), Mathematics Department of MIT, E18-374, 77 Massachusetts Avenue, cambridge, MA 02139, and **Jason Miller**, Mathematics Department of MIT, E18-470, 77 Massachusetts Avenue, cambridge, MA 02139. *Intersections of SLE paths.*

SLE curves are introduced by Oded Schramm as the candidates of the scaling limit of discrete models. In this talk, we first describe basic properties of SLE curves and their relation with discrete models. Then we summarize the Hausdorff dimension results related to SLE curves, in particular the new results about the dimension of cut points and double points. Third we introduce Imaginary Geometry, and from there give the idea of the proof of the dimension results. (Received June 18, 2014)

1106-60-98 **John P Nolan*** (jpnolan@american.edu), Math/Stat Department, Gray Hall, American University, 4400 Massachusetts Avenue, NW, Washington, DC 20016-8050, and **U. Tuncay Alparslan** (alparsla@american.edu), Math/Stat Department, Gray Hall, American University, 4400 Massachusetts Avenue, Washington, DC 20016-8050. *Measuring independence for stable distributions.*

There are several measures of dependence for stable laws, but none of them characterize independence. We propose a measure that uses the directional scale function and does characterize independence. Properties of this measure are explored and a test based on the sample estimations of the directional scale function is given. (Received July 15, 2014)

1106-60-104 **Indranil SenGupta*** (indranil.sengupta@ndsu.edu), NDSU Dept 2750, Minard Hall 408E12, Department of Mathematics, North Dakota State University, Fargo, ND 58108-6050. *Heavy-tailed Lévy processes in pricing exotic options in finance.*

In this talk applications of heavy-tailed distributions will be presented in connection with pricing different exotic options in financial market. Dynamics of stock price will be modeled using various exponential Lévy processes and partial integro-differential equations (PIDE) will be derived for the option price. Such equations will be solved using various transform methods. Numerical simulations will be provided to calibrate the model with real market data for exotic options such as Asian options, Lookback options and Barrier options. (Received July 16, 2014)

1106-60-112 **Michael Grabchak*** (mgrabcha@uncc.edu), UNC Charlotte, Department of Mathematics and Statistics, 9201 University City Blvd, Charlotte, NC 28223. *Does value-at-risk encourage diversification when losses follow tempered stable or more general Lévy processes?*

We address the question of when portfolio selection based on Value-at-risk encourages diversification. Specifically, we give sufficient conditions for the case when losses follow a Lévy process. When the process has finite variation, these conditions are also necessary. We then specialize our results to the case when losses have tempered stable distributions. (Received July 17, 2014)

1106-60-173 **Qi He***, 425 Rowland Hall, Irvine, CA 92697, and **Jack Xin**. *Hybrid Deterministic-Stochastic Gradient Langevin Dynamics for Bayesian Learning.*

In this paper, we propose a new algorithm to obtain Bayesian posterior distribution by a hybrid deterministic-stochastic gradient Langevin dynamics. To speed up convergence, it is common to use stochastic gradient method to approximate the gradient by sampling a subset of the large dataset. Stochastic gradient methods make progress fast initially, however, it is often slow as the iterations approach the desired solution. In contrast, full gradient methods converge at the expense of evaluating the full gradient at each iteration. To overcome the disadvantages of these two methods, we develop a hybrid method that has the advantages of both approaches for Bayesian posterior distribution. We present mathematical proof for the convergence of our algorithm, and show its fast convergences by numerical simulations. (Received August 04, 2014)

1106-60-190 **Omer Tamuz*** (omertamuz@gmail.com), 41 Magnolia Avenue, Cambridge, MA 02138. *Convergence and learning in majority dynamics on infinite graphs.*

We discuss a few recent results regarding majority dynamics, and present some compelling probabilistic and combinatorial open problems. (Received August 07, 2014)

1106-60-269 **Susan Holmes**, **Simon Rubinstein-Salzedo*** (simonr@stanford.edu) and **Christof Seiler**. *Positive Curvature and Hamiltonian Monte Carlo.*

Recently, Joulin and Ollivier have defined a notion of curvature for Markov chains and have shown that one can obtain bounds on mixing times assuming that the curvature is always positive and bounded away from zero. In this talk, we apply their techniques to the setting of Hamiltonian Monte Carlo, a modification of the classical Metropolis-Hastings algorithm for sampling from a target distribution that sees more geometric information about the target distribution. We then show that, in several important cases in high dimensions, the curvature of a Hamiltonian Monte Carlo chain is positive. We thus obtain polynomial (in the dimension) mixing time bounds. (Received August 17, 2014)

1106-60-328 **Yankeng Luo*** (luo7@purdue.edu), 150 N. University Street, West Lafayette, IN 47907, and **J. Figueroa-Lopez** (figueroa@purdue.edu), 250 N. University Street, West Lafayette, IN 47907. *Small-time expansions for state-dependent local jump-diffusion models with infinite jump activity.*

Motivated by the European call option pricing, we construct a jump-diffusion process $\{X_t\}_{t\geqslant 0}$, starting from $x\in\mathbb{R}$ and solving a stochastic differential equation (SDE), which is driven by a Brownian motion and an independent pure jump component exhibiting state-dependent jump intensity and infinite jump activity. We obtain the second order expansion, in a small time t, of the tail probability $\mathbb{P}[X_t \geqslant x+y]$, for any $y>0$. A numerical example shows the accuracy of this expansion. As an application of this expansion and a suitable change of the underlying probability measure, we obtain the second order expansion, in a short maturity t, of out-of-the-money European call option prices when the underlying stock price is modeled as the exponential of the jump-diffusion process $\{X_t\}_{t\geqslant 0}$ under the risk-neutral probability measure. (Received August 22, 2014)

1106-60-486 **Richard Kenyon** and **Mei Yin*** (mei.yin@du.edu), 2280 S Vine St, Denver, CO 80208. *On the asymptotics of constrained exponential random graphs.*

The unconstrained exponential family of random graphs assumes no prior knowledge of the graph before sampling, but in many situations partial information of the graph is already known beforehand. A natural question to ask is what would be a typical random graph drawn from an exponential model subject to certain constraints? Using the theory of large deviations, we present some general results for the constrained model and in particular the exact asymptotics for the conditional normalization constant. Part of this talk is based on joint work with Richard Kenyon. (Received August 30, 2014)

1106-60-527 **Elchanan Mossel**, **Joseph Neeman*** (joeneeman@gmail.com) and **Allan Sly**. *A threshold for reconstruction in stochastic block models.*

A stochastic block model is a random graph model that exhibits a community structure: vertices are assigned labels, and then edges are added independently at random with probabilities depending on the labels of their endpoints. For sparse stochastic block models, there is a threshold below which it is not possible to reconstruct the communities given only the graph. We will discuss the proof of this result, and some related problems. (Received September 01, 2014)

1106-60-546 **Mark M. Meerschaert**, **René L. Schilling** and **Alla Sikorskii*** (sikorska@stt.msu.edu), 619 Red Cedar Road, Department of Statistics and Probability, Michigan State University, East Lansing, MI 48824. *Stochastic Solutions for fractional wave equations.*

A fractional wave equation replaces the second time derivative by a Caputo derivative of order between one and two. In this paper, we show that the fractional wave equation governs a stochastic model for wave propagation, with deterministic time replaced by the inverse of a stable subordinator whose index is one half the order of the fractional time derivative. (Received September 02, 2014)

1106-60-689 **Gennady Samorodnitsky*** (gs18@cornell.edu), School of ORIE, Cornell University, Ithaca, NY 14850, and **Sidney Resnick**, **Don Towsley**, **Richard David**, **Amy Willis** and **Phyllis Wan**. *Nonstandard regular variation of in-degree and out-degree in the preferential attachment model.*

For the directed edge preferential attachment network growth model studied by Bollobas et al. (2003) and Krapivsky and Redner (2001), we prove that the joint distribution of in-degree and out-degree has jointly regularly varying tails. Typically the marginal tails of the in-degree distribution and the out-degree distribution have different regular variation indices and so the joint regular variation is non-standard. Only marginal regular variation has been previously established for this distribution in the cases where the marginal tail indices are different. (Received September 04, 2014)

1106-60-718 **Aaron Abrams** and **Richard Kenyon***, 151 Thayer St, Providence, RI 02912. *Area-one rectangulations.* Preliminary report.

We study the (rational) map from conductances to edge energies in a finite resistor network. We show that, for the simplest boundary conditions consisting of a potential drop across two vertices, the map is surjective, and of degree equal to the number of acyclic orientations with a unique source and sink at the relevant boundary points.

As an application we show that any planar graph can be realized as a rectangle tiling with equal area rectangles. (Received September 05, 2014)

1106-60-736 **M. Sambandham*** (msambandham@yahoo.com), Department of Mathematics, Atlanta, GA 30314, and **M. Sudharani**. *Real Zeros of a Random Algebraic Polynomial with Infinite Variance.*

We consider a random algebraic polynomial whose coefficients are dependent random variables with constant correlation between any two random variables. We find the upper bound of the number of real zeros. A few special cases are also discussed. (Received September 05, 2014)

1106-60-737 **Divine Wanduku***, 2400 Interstate Dr., Lakeland, FL 33810. *A Vector-born Disease Scale-Structured Network Delay Stochastic Epidemic dynamic model.* Preliminary report.

A complete stochastic analysis of an SIRS delayed epidemic dynamic model is presented for a vector-born disease in a two-scale structured population. The distributed time delay accounts for the varying incubation period of the infectious agent in the vector. Furthermore, the infectious vector population is proportional to the infectious human population present at the onset of the incubation period. In addition, the disease dynamics is influenced by random environmental perturbations leading to variability in the disease transmission process. The stochastic asymptotic stability of the disease free equilibrium is investigated and the impact on the emergence, propagation and resurgence of the disease is verified. The results of the study are exhibited in different special human mobility patterns. The presented results are demonstrated by numerical simulation results. (Received September 05, 2014)

1106-60-751 **Daniel O'Malley*** (omalled@lanl.gov), **Velimir V Vesselinov** and **John H Cushman**. *Random dispersion coefficients and Tsallis entropy.*

Brownian motion, the classical dispersive process, maximizes the classical Boltzmann-Gibbs entropy. In recent years, the Tsallis q-entropy has been developed as an alternative to the classical entropy for systems in which are non-ergodic. We demonstrate how Brownian motion can be generalized so that the Tsallis entropy is maximized rather than the Boltzmann-Gibbs entropy. This generalization results simply from using a random dispersion coefficient, and we derive the distribution of this coefficient as a function of q for $1 < q < 3$. Applications to transport in the subsurface are considered. (Received September 05, 2014)

1106-60-813 **Sarah Wolff*** (sarah.e.wolff@dartmouth.edu). *Random Walks on the BMW Monoid: an Algebraic Approach.*

We consider the problem of randomly generating basis elements of a semisimple algebra; namely, the Birman Murakami Wenzl (BMW) monoid basis of the BMW algebra. We present a generalized metropolis scan algorithm that translates to a natural random walk on the BMW monoid. Interpreting this walk as a left multiplication operator in the BMW algebra then allows for analysis using tools from representation theory and Fourier analysis. (Received September 07, 2014)

1106-60-836 **Francois Baccelli** and **Ngoc Mai Tran*** (tran.mai.ngoc@gmail.com). *Zeroes of Random Tropical Polynomials, Random Polytopes and Stick-breaking.*

Stochastic tropical geometry is the study of linear functionals of random tropical varieties. It is an exciting new field at the interface of algebraic geometry, probability and combinatorics, with connections to many others. In this work, we study the simplest possible case: the number of zeroes of a randomtropical polynomial.

Specifically, if a tropical polynomial has coefficients independent and identically distributed according to some distribution F, then its number of zeroes satisfies a central limit theorem. The scaling is governed by how fast F decays near 0. This can be seen as a local universality result for zeros ofrandom tropical polynomials.

Our proof draws on connections between random partitions, renewal theory and random polytopes. In this talk, I sketch the main proof ideas and discuss open questions in the field of stochastic tropical geometry.

Joint work with Francois Baccelli. (Received September 07, 2014)

1106-60-907 **Robert Alohimakalani Yuen*** (bobyuen@umich.edu) and **Stilian A Stoev**. *Upper bounds on Value-at-Risk for the maximum portfolio loss.*

Extremal dependence of the losses in a portfolio is one of the most important features that should be accounted for when estimating Value-at-Risk (VaR) at high levels. Max-stable processes provide a principled framework for the modeling and estimation of extremal dependence. In practice, however, this involves dealing with a challenging infinite dimensional parameter. Here, following recent developments in Strokorb and Schlather (2013), we propose to represent extremal dependence via the Tawn–Molchanov (TM) model, which is finite dimensional. Every max–stable random vector $\mathbf{X}$ can be associated with a TM max-stable vector $\mathbf{Y} = \mathrm{TM}(\mathbf{X})$ so that the *extremal coefficients* of $\mathbf{X}$ and $\mathbf{Y}$ *match* and at the same time $\mathbf{Y}$ stochastically dominates $\mathbf{X}$ in the lower orthant order. This result readily yields an optimal upper bound on the Value-at-Risk $\mathrm{VaR}_\alpha(\mathbf{X}^\vee)$ of the maximum portfolio loss $\mathbf{X}^{\vee} := \max_{j=1,\dots,d} X_j$. We discuss some challenges in extending our framework to bound Value-at-Risk for the *sum of dependent losses*. (Received September 08, 2014)

1106-60-960 **Patrick A Assonken*** (patrick13@mail.usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, Tampa, FL 33620-5700, and **Gangaram S Ladde** (gladde@usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, Tampa, FL 33620-5700. *Levy-type Stochastic Dynamic Modeling of Option Pricing Process under Semi-Markovian Structural Perturbations.* Preliminary report.

In this work, we consider a stock price process subjected to idiosyncratic Levy jumps and global structural changes attributed to interventions due to a Semi Markov process. The Semi Markov process decomposes the time domain of the price process into intervals where it operates as a mere Levy-Ito process, whereas Levy jumps decompose the space domain of the operating Levy process. We derive an infinitesimal generator for the stock price process and a closed form expression for the conditional characteristic function of the log return of a stock price process. The former could be used to derive a PIDE satisfied by exotic option price processes, while the latter could be used to retrieve the risk neutral densities via the Fourier transform and price European Vanilla Options. We use the risk neutral pricing formula based on an equivalent Martingale measure derived through an Esscher transformation. We derive a couple of formula for Vanilla European Call Option prices. The first formula is a consequence of Carr and Madan transformation under deterministic interest rate and the second is a modification of Ghosh and Goswami formula. (Received September 09, 2014)

1106-60-1004 **Greta Panova*** (panova@math.upenn.edu), University of Pennsylvania, Mathematics Department, Philadelphia, PA 19104. *Asymptotics of symmetric functions: applications to some integrable models.*

We develop methods to study the asymptotics of symmetric functions of representation theoretic origins. Using these results, we study the behavior of certain models from statistical mechanics as the underlying mesh size goes to 0. In this talk we will focus on lozenge tilings of various domains (including domains with free boundaries), but the methods have also been applied to the 6-vertex model with domain wall boundary conditions (alternating sign matrices) and the O(1) dense loop model. Results include the recovery of GUE-eigenvalue distribution for the lozenge positions near the boundary and the existence of limit shapes of the height functions (plane partitions) for free boundary domains.

This talk is based on two papers, the main one is joint work with Vadim Gorin. (Received September 09, 2014)

1106-60-1016 **Zheng Wei*** (weizheng@nmsu.edu), 2217 Hagerty Rd Apt 12, Las Cruces, NM 88001, and **Tonghui Wang**, **Baokun Li** and **Phoung Anh Nguyen**. *The joint belief function and Shapley value for the joint cooperative game.*

In this paper, the characterization of the joint distribution of random set vectors by the belief function is investigated and the joint game in terms of the characteristic function is given. The bivariate Shapley value of a joint cooperative game is obtained through both cores and games. Formulas for the Shapley value derived from two different methods are shown to be identical. For illustration of our main results, several examples are given. (Received September 09, 2014)

1106-60-1022 **Jessica L. Jones*** (jonesj.rpi@gmail.com), **Joyce R. McLaughlin** and **Daniel Renzi**. *Statistical Analysis of Shear Wave Speed Recovery Using the Direct Algorithm and the Arrival Time Algorithm.*

Elastography is a non-invasive method which images the mechanical properties of tissue, such as tissue stiffness. The elastography experiment is performed by inducing a shear wave in tissue and measuring the resulting interior displacement using ultrasound. From these displacements, we can then calculate the arrival time of the shear wave. This arrival time data allows us to recover the shear wave speed, an indicator of tissue stiffness. We consider two methods to recover the shear wave speed using the arrival time of the wave, and analyze the effect of Gaussian noise in the arrival time data on the recovered shear wave speed for each algorithm. (Received September 09, 2014)

1106-60-1169 **Ugur Tuncay Alparslan***, Department of Mathematics and Statistics, 4400 Massachusetts Ave. NW, Washington, DC 20016. *Ruin in stationary stable environments: Beyond the univariate model.* Preliminary report.

Asymptotic behavior of the ruin probability in a univariate model is a well-defined and widely explored subject of applied probability. However, when the "claims" are modeled by a random vector or a random field, study of multiple ruin sets can be motivated. In this talk we will present preliminary results for the tail behavior of ruin probabilities associated with certain types of ruin sets, and stationary sum-stable vectors and random fields, which rely on the ergodic structure of such objects. (Received September 11, 2014)

1106-60-1199 **Joel A. Tropp*** (`jtropp@cms.caltech.edu`), 1200 E. California Blvd., MC 305-16, Pasadena, CA 91125. *Concentration inequalities for random matrices.*

Random matrices now play a role in many areas of theoretical, applied, and computational mathematics. In contemporary problems, however, it is common to encounter random matrices that do not submit to classic methods. Over the last fifteen years, researchers have developed a new set of user-friendly tools, called *matrix concentration inequalities*, that can provide valuable information about modern random matrices.

This talk offers an invitation to the field of matrix concentration inequalities that is aimed at students and researchers in other areas. The presentation begins with an introduction to random matrix theory and the fundamental probability inequalities for scalar random variables. It describes a flexible model for random matrices that is suitable for many applications, and it summarizes the basic matrix concentration inequalities. It concludes with examples drawn from algorithms and combinatorics, statistics and signal processing, scientific computing, and beyond.

This presentation accompanies the SIAM Mini-Symposium on Matrix Concentration Inequalities. This session includes six prominent young researchers who have used matrix concentration tools in their work. Their talks explore other problems you can address with these methods. (Received September 15, 2014)

1106-60-1323 **Tolulope Rhoda Fadina*** (`tfadina@math.uni-bielefeld.de`), International Graduate College, Stochastics, and Real World Models, Bielefeld University, Universitaetstr 25, 33615 Bielefeld, NRW, Germany. *Hyperfinite Construction of G-expectation.*

We refine the discretization of G-expectation by Y. Dolinsky, M. Nutz, and M. Soner (*Stochastic Processes and their Applications, 122 (2012), 664–675*), in order to obtain a discretization of sublinear expectation where the martingale laws are defined on a finite lattice rather than the whole set of reals. We then use this result to devise an alternative construction of G-expectation in the framework of Robinsonian nonstandard analysis. (Received September 12, 2014)

1106-60-1435 **Etsuo Segawa*** (`e-segawa@m.tohoku.ac.jp`), Aoba, Sendai, 980-8579, Japan. *Quantum walks on hyperbolic graphs.*

We consider a special class of quantum walks including the Grover walk. We show that every quantum walk in this class has an underlying cellar automaton which can be regarded as a spatial and temporal discrete analogue of a wave equation. It is known that the spectrum of the quantum walk on finite graph is obtained by the cellar automaton and a spatial structure of the graph; named cycles. In this talk, on infinite graphs, we discuss the case that another geometric structure; named hyperbolicity, is also reflected to its spectrum and behaviors of the quantum walk. (Received September 13, 2014)

1106-60-1473 **Lester Mackey*** (`lmackey@stanford.edu`), **Michael I Jordan**, **Richard Y Chen**, **Brendan Farrell** and **Joel A Tropp**. *Stein's Method for Matrix Concentration.*

Motivated by the problem of estimating matrices from a small number of random measurements, I will show how Stein's method of exchangeable pairs can be used to derive concentration inequalities for matrix-valued random elements. When applied to a sum of independent random matrices, this approach yields matrix generalizations of the classical inequalities due to Hoeffding, Bernstein, Khintchine, and Rosenthal. The same technique delivers bounds for sums of dependent random matrices and more general matrix functionals of dependent random elements. (Received September 13, 2014)

1106-60-1484 **Yumin Wang*** (`xixizi11@gmail.com`), 2006 Woodriver Dr Apt 19, Carbondale, IL 62901. *Quantile Hedging in Bermuda put option.* Preliminary report.

An investor faced with a contingent claim may eliminate risk by (super-)hedging in a financial market. As this is often quite expensive, we study partial hedges which require less capital and reduce the risk. In this paper, we determine quantile hedges which succeed with maximal probability, given a capital constraint on a Bermuda put option. (Received September 13, 2014)

1106-60-1521 **Turgay Bayraktar*** (`tbayrakt@syr.edu`), 215 Carnegie Building, Syracuse, NY 13244-1150. *Asymptotic Zero Distribution of random polynomials.*

A classical result due to Kac and Hammersley asserts that zeros of a random complex polynomial tend to accumulate on the unit circle as as its degree grows provided the coefficients are i.i.d. standard real or complex Gaussians. In this talk, I will discuss the asymptotic zero distribution of random combinations of orthogonal polynomials in several complex variables. I will explain how one can prove new results by means of pluri-potential theory. Namely, normalized zero measures of m i.i.d random polynomials, orthonormalized on a regular compact set $K \subset \mathbb{C}^m$, are almost surely asymptotic to the equilibrium measure of K. (Received September 13, 2014)

1106-60-1530 **Bruce K. Driver** (bdriver@math.ucsd.edu) and **Nathaniel Eldredge*** (neldredge@unco.edu), University of Northern Colorado, 501 20th St, Box 122, Greeley, CO 80634, and **Tai Melcher** (melcher@virginia.edu). *Hypoelliptic heat kernels on infinite-dimensional Heisenberg groups.*

A hypoelliptic diffusion is, roughly speaking, a continuous Markov process which locally is only allowed to move in certain specified directions, yet globally is able to roam throughout its state space. A simple example is hypoelliptic Brownian motion on the 3-dimensional Heisenberg group, which can be viewed as a 2-dimensional standard Brownian motion coupled with its Lévy area process. It is a classical result that this process admits a smooth heat kernel.

I will discuss an extension of this result to infinite-dimensional analogues of the Heisenberg group, modeled on abstract Wiener space, as introduced by Driver and Gordina. We show that hypoelliptic Brownian motion on such a group admits (in an appropriate sense) a heat kernel, which enjoys quasi-invariance properties that can be interpreted as smoothness. Our work recovers and extends results of Baudoin–Gordina–Melcher, which they obtained via detailed curvature-dimension estimates, but our methods are based on elementary stochastic calculus. In particular, we obtain new L^p estimates on higher derivatives of the heat kernel. (Received September 13, 2014)

1106-60-1567 **John C Wierman*** (wierman@jhu.edu), Dept. of Applied Mathematics & Statistics, 100 Whitehead Hall, Johns Hopkins University, Baltimore, MD 21286. *On Percolation Threshold Curves for 3-Uniform Hypergraphs.* Preliminary report.

Since the origins of percolation theory in the 1950s, a major challenge has been to determine the percolation threshold exactly for a large class of lattices. Research by Ziff and Scullard identified a class of lattices formed by replacing each hyperedge of a 3-uniform self-dual periodic hypergraph by a “generator” graph, for which the solution of a simple equation provides the exact percolation threshold. The result may be re-interpreted in terms of a “threshold curve,” which provides the solution for any generator in a 3-uniform self-dual periodic hypergraph. The approach may be extended to other 3-uniform periodic hypergraphs, for which an exact threshold curve has not been found, although bounds for it may be determined. (Received September 14, 2014)

1106-60-1627 **Sidney I Resnick*** (sir1@cornell.edu), Cornell University, ORIE, Rhodess 284, Ithaca,, NY 14853. *Tauberian Theory for Multivariate Regularly Varying Distributions with Application to Preferential Attachment Networks.*

Abel-Tauberian theorems relate power law behavior of distributions and their transforms. We formulate and prove a multivariate version for non-standard regularly varying measures on the positive p-dimensional quadrant and then apply it to prove that the joint distribution of in- and out-degree in a directed edge preferential attachment model has jointly regularly varying tails. (Joint with G. Samorodnitsky) (Received September 14, 2014)

1106-60-1668 **Zhixin Yang*** (yangzhix@uwec.edu), HHH 420 Department of Mathematics, University of Wisconsin-Eau Claire, Eau Claire, WI 54701, and **George Yin** and **Qing Zhang**. *Mean-Variance Type Controls Involving a Hidden Markov Chain: Models and Numerical Approximation.*

Motivated by applications arising in networked systems, this work examines controlled regime-switching systems that stem from a mean-variance formulation. A main point is that the switching process is a hidden Markov chain. An additional piece of information, namely, a noisy observation of switching process corrupted by white noise is available. We focus on minimizing the variance subject to a fixed terminal expectation. Using the Wonham filter, we convert the partially observable system to a completely observable one first. Since closed-form solutions are virtually impossible to be obtained, a Markov chain approximation method is used to devise a computational scheme. Convergence of the algorithm is obtained. A numerical example is provided to demonstrate the results. (Received September 14, 2014)

1106-60-1673 **Quan Yuan***, 656 W Kirby FAB 1250, Detroit, MI 48202, and **G Yin**. *Particle Swarm Optimization: A Stochastic Approximation Approach.*

Recently, much progress has been made on particle swarm optimization (PSO). A number of works have been devoted to analyzing the convergence of the underlying algorithms. Nevertheless, in most cases, rather simplified hypotheses are used. Moreover, up to now, not much is known regarding the convergence rates of particle swarm. We consider a general form of PSO algorithms, and analyze asymptotic properties of the algorithms using stochastic approximation methods. We introduce four coefficients and rewrite the PSO procedure as a stochastic approximation type iterative algorithm. Then we analyze its convergence using weak convergence method. It is proved that a suitably scaled sequence of swarms converge to the solution of an ordinary differential equation. We also establish certain stability results. Moreover, convergence rates are ascertained by using weak convergence method. A centered and scaled sequence of the estimation errors is shown to have a diffusion limit. (Received September 14, 2014)

1106-60-1687 **Dong Hyun Cho*** (`j94385@kyonggi.ac.kr`), Department of Mathematics, Kyonggi University, Suwon, Kyonggido 443-760, South Korea. *Generalized conditional Wiener integrals and their applications over analogues of Wiener paths.*

Let $C[0,T]$ denote a generalized Wiener space and let $\{e_j : j = 1, 2, \cdots\}$ be a complete orthonormal subset of $L_2[0,T]$. Suppose that each e_j is of bounded variation. For each $j \in \mathbb{N}$ define $z_j : C[0,T] \to \mathbb{R}$ by the stochastic integral

$$z_j(x) = \int_0^T e_j(s)dx(s),$$

where the integrals denote the Paley-Wiener-Zygmund stochasticintegral. For each $n \in \mathbb{N}$ define $Z_n : C[0,T] \to \mathbb{R}^n$ and $Z : C[0,T] \to \mathbb{R}^{\aleph_0}$ by

$$Z_n(x) = (x(0), z_1(x), \cdots, z_n(x))$$

and

$$Z(x) = (x(0), z_1(x), z_2(x), \cdots).$$

In this talk we derive two simple formulas for generalized conditional Wiener integrals of functions on $C[0,T]$ with the conditioning functions Z_n and Z which contain the initial distribution. We derive a joint probability density function of random variables $x(0), z_1(x), \cdots, z_n(x)$ which have a multivariate normal distribution if the initial distribution is the Dirac measure concentrated at 0. As applications of these simple formulas and the normal distribution we evaluate generalized conditional Wiener integrals of the function $\exp\{\int_0^T Z(x,t)dm_L(t)\}$ including a time integral on $C[0,T]$. (Received September 15, 2014)

1106-60-1742 **Andreas Basse-O'Connor** and **Jan Rosinski*** (`rosinski@math.utk.edu`). *On infinitely divisible semimartingales.*

The question whether a given process with long memory and heavy tails is a semimartingale is of importance in stochastic modeling, where such processes are used as a driving random motion for stochastic differential equations. We consider this question in the context of infinitely divisible processes. We show that the problem when any such process is a semimartingale can often be reduced to a path property, when a certain associated infinitely divisible process is of finite variation. This gives the key to characterize the semimartingale property for many processes of interest, including linear fractional processes, moving averages, supOU processes, and more generally, Volterra processes driven by Lévy processes. (Received September 15, 2014)

1106-60-1821 **Brian Christopher Kirk*** (`briankirk@mail.adelphi.edu`), 189 Elderberry Road, Mineola, NY 11501, and **Salvatore P Giunta** (`sgiunta@adelphi.edu`), 152 bismark ave, valley stream, NY 11581. *Monty Hall Returns: Analyzing Cognitive Probabilistic Models.*

An individual, when faced with a meaningful decision, must necessarily create a probabilistic model of the situation before them to guide their choice. We will present a statistical analysis of the responses of various individuals faced with the Monty Hall Problem. We will also discuss statistical correlation and regression between the complexity and accuracy of the individuals' extemporaneously created probabilistic models, using the Conditional Probability Solution as the baseline for the analysis. (Received September 15, 2014)

1106-60-1858 **Shahrzad Haddadan** and **Peter Winkler***, peter.winkler@dartmouth.edu. *Permutations and Spin Systems.*

We formulate certain Markov chains on permutations as spin systems in order to take advantage of results about Glauber dynamics. (Received September 15, 2014)

1106-60-1899 **Ernest Jum*** (`ejum@utk.edu`) and **Jan Rosinski** (`rosinski@math.utk.edu`). *Simulation of stochastic differential equations driven by pure jump Levy processes with infinite jump activity.* Preliminary report.

We consider the problem of simulation of stochastic differential equations driven by pure jump Levy processes with infinite jump activity. Examples include, the class of stochastic differential equations driven by stable and tempered stable Levy processes, which are suited for modeling of a wide range of heavy tail phenomena.

We replace the small jump part of the driving Levy process by a suitable Brownian motion, as proposed by Asmussen and Rosinski, which results in a jump-diffusion equation. We obtain desired mean-square and weak error estimates for the error resulting from this step. Combining this with numerical schemes for jump diffusion equations, we provide a good approximation method for the original stochastic differential equation that can also be implemented numerically. We complement these results with concrete error estimates and simulation.
(Received September 16, 2014)

1106-60-1923 **Balram Rajput*** (rajput@math.utk.edu), 1403 Circle Drive, Knoxville, TN TN. *On Uniform Comparison of Tail Probabilities of a certain class of Banach Valued Random Vectors.* Preliminary report.

We shall present a few results that provide uniform comparison of tail probabilities of Banach valued random vectors and their symmetric counterparts. These in particular apply to the class of stable/semi-stable random vectors. We shall also discuss some applications of these results. The first part of the talk will be a survey of known results, then we shall present a few new results, and finally we shall point out a few related problems.

(Part of this talk is based on a joint work with Jan Rosinski.) (Received September 15, 2014)

1106-60-2013 **Xiang Li*** (lisha@math.berkeley.edu), 367 Evans Hall, UC Berkeley, Berkeley, CA 94620, and **Balázs Szegedy**, MTA Alfréd Rényi Institute of Mathematics. *A case for graph limits: The Logarithmic Calculus and Application to Sidorenko's Conjecture.*

We use the graph limit setting to tackle the Erdos-Simonovits-Sidorenko's Conjecture. The conjecture posits an inequality for subgraph densities, which roughly says that among all graphs, the Erdos-Renyi random graph minimizes the subgraph count of any bipartite graph. The inequality is a refinement of the Forcing conjecture in extremal combinatorics, and relates to quasi-randomness. The graph limit setting allows us to develop a unified perspective to prove the result for previous cases and greatly expands the family of graphs for which the conjecture is true. We are able to develop an algebra of graph operations that preserves Sidorenko's property, which we dub the 'Logarithmic Calculus'. The approach opens topological interpretations and proposes open problems to help solve Sidorenko's Conjecture. (Received September 15, 2014)

1106-60-2025 **Mark M Meerschaert*** (mcubed@stt.msu.edu) and **Peter Straka**. *SEMI-MARKOV APPROACH TO CONTINUOUS TIME RANDOM WALK LIMIT PROCESSES.*

Continuous time random walks (CTRWs) are versatile models for anomalous diffusion processes that have found widespread application in the quantitative sciences. Their scaling limits are typically non-Markovian, and the computation of their finite-dimensional distributions is an important open problem. This paper develops a general semi-Markov theory for CTRW limit processes in R^d with infinitely many particle jumps (renewals) in finite time intervals. The particle jumps and waiting times can be coupled and vary with space and time. By augmenting the state space to include the scaling limits of renewal times, a CTRW limit process can be embedded in a Markov process. Explicit analytic expressions for the transition kernels of these Markov processes are then derived, which allow the computation of all finite dimensional distributions for CTRWlimits. Two examples illustrate the proposed method. (Received September 15, 2014)

1106-60-2179 **Gaoran Yu***, 116 W University Pkwy, Apt 602, Baltimore, MD 21210. *Network Flow Approach in Solving Rigorous Bounds of Percolation Thresholds of Archimedean Lattices.* Preliminary report.

In percolation theory, a major problem is finding the percolation threshold at which an infinite open cluster begins to exist. Exact percolation threshold solutions are extremely rare. In 1990, Wierman introduced the substitution method to determine rigorous bounds for percolation thresholds. The substitution method compares two subgraphs (substitution regions) from two lattices so that the probability measure of one subgraph is stochastically larger than the probability measure of the other subgraph.

To prove the stochastic ordering, one straightforward method is by listing all the upsets and comparing their corresponding probabilities with respect to the two probability measures. An alternative choice is by the connection between stochastic ordering and network-flow, introduced by Preston. With a carefully designed network flow structure, one is able to prove stochastic ordering by solving for the max-flow value. This approach has been proved to be more efficient, but has the disadvantage of a relatively large numerical error. We will discuss some feasible improvements to reduce the error and provide latest results of the bounds for the percolation threshold of some common Archimedean lattices.
(Received September 16, 2014)

1106-60-2180 **Amanda A Groccia*** (amandagroccia@gmail.com), 102 Lone Oak Drive, New Milford, CT 06776. *Stochastic Differential Equations: Killer Shrimp.* Preliminary report.

Stochastic differential equations yield solutions that are continuous-time stochastic processes. We show how stochastic differential equations can be applied to a very specific ecological system which examined canabalistic shrimp in Southern German waters, which were experiencing several drastic population changes. We specifically modeled a very special case of the predator-prey model, known as mutual predation in which a canabalistic term was added. This model was then later nondimensionalized to determine the longterm trends when additive noise was introduced. These equations gave rise to useful methods for numerically approximating longterm trends in these shrimp populations. (Received September 16, 2014)

1106-60-2319 **Adina Oprisan*** (aoprisan@barry.edu). *Asymptotic results for additive functionals of Semi-Markov processes.*

In this talk we consider additive functionals of continuous time Semi-Markov processes with an arbitrary state space E, $W_t = \int_0^t f(X_s)\,ds$ where f is a Borel measurable function. Several important results are known for the case in which f is bounded and in this talk we discuss a more general class for which functional central limit theorem, almost everywhere central limit theorem and large deviation principle hold true. (Received September 16, 2014)

1106-60-2340 **Daniel Conus**, **Vladimir Dobric** and **Mackenzie Wildman*** (mackenzie.wildman@gmail.com). *Gaussian Markov Processes and Option Pricing Theory.*

I will discuss the development, testing, and implementation of a less restrictive alternative to the Black-Scholes model for pricing derivatives. By relaxing the assumption of past independence but retaining the Markovian property, we are developing a less restrictive but equally efficient model. This is achieved by replacing Black-Scholes' underlying process, Brownian motion, with a certain Gaussian Markov process. This is joint work with Daniel Conus and Vladimir Dobric. (Received September 16, 2014)

1106-60-2347 **Vindya Kumari Pathirana*** (vkumari@mail.usf.edu), 4202 E. Fowler Ave. CMC 342, University of South Florida, Tampa, FL 33620, and **Kandethody M Ramachandran** (ram@usf.edu), 4202 E. Fowler Ave. CMC 342, University of South Florida, Tampa, FL 33620. *Multistep-ahead forecasting in FX rates using K-Nearest Neighbor Algorithm with Mahalanobis Distance.*

Given that exchange rates series exhibit high volatility, it is widely recognized that they are extremely difficult to forecast. Besides, FX data are non-linear and one of the noisiest. Forecasting through non-linear dynamical systems is becoming more and more relevant due to these natures of the data. Nearest Neighbor Algorithms are such most popular non-linear pattern recognition methods that outperform the available linear forecasting methods. In this paper we suggest to adapt nearest neighbor algorithm with Mahalanobis distance to choose the neighbors for the forecasting. Mahalanobis distance is used due to high correlation between the vectors resulting from time series segments. Also, we suggest to adapting auto regression in the forecasting of FX rates. We compare the performance of Nearest Neighbor forecasting with Auto regression based algorithm with popular linear regression based algorithms. Also, we will show how our method affects the decision to sell and buy. (Received September 16, 2014)

1106-60-2402 **Karl Rohe*** (karlrohe@stat.wisc.edu), **Mohammad Khabbazian** and **Haoyang Liu**. *Statistical properties of average linkage hierarchical clustering under the Stochastic Blockmodel.*

Agglomerative hierarchical clustering outputs a dendrogram that can estimate hierarchical structure (e.g. Clauset-Moore-Newman 2008, Ahn-Bagrow-Lehmann 2010). It was first proposed in Anderson 1962. Various forms of this algorithm have found wide applicability across various domains. The algorithm is agglomerative; at the first step, every data point is a unique set and at every successive step, the two closest sets are joined together as a new set. The algorithm stops when there is only one set. This requires (1) pairwise measurements between all points (either similarities or distances) and (2) a "linkage" that combine these pairwise measurements into measurements between sets of points.

Taking the arithmetic mean of pairwise measurements in (2) yields one of the most popular forms of this algorithm called "average linkage." Despite its popularity, this form of the algorithm has no known statistical estimation results. This talk will relate average linkage to spectral graph theory. Using the spectral properties of the Stochastic Blockmodel, we show that this classical algorithm is weakly consistent under the Stochastic Blockmodel with pairwise similarity "# of common neighbors". We provide a fast implementation for sparse graphs. (Received September 16, 2014)

1106-60-2539 **John C Wierman** and **Shaun W McCarthy*** (smccart9@jhu.edu), 3900 n charles st, Apt 1211, Baltimore, MD 21218. *Improving the upper bound for the bond percolation threshold of the cubic lattice.* Preliminary report.

Nearly all rigorous results on bond percolation thresholds are for two-dimensional lattices. Very little is known about three dimensional lattices, which are more relevant for physical application. By considering essentially two-dimensional subgraphs of the cubic lattice, and comparing them to solved two-dimensional lattices - such as the square, dice, and bowtie lattice - we find an improved upper bound for the bond percolation threshold of the cubic lattice. We use the substitution method, which is based on stochastic ordering. (Received September 16, 2014)

1106-60-2549 **George Mytalas***, mytalas@njit.edu, New York, NY 11209. *An M/G/1 system with delayed feedback times and vacations.* Preliminary report.

We consider an M/G/1 queueing system with individual arrivals subject to server vacations. The server is turned off as soon as the system empties and remains off waiting for the first customer to serve. During the vacation period arriving customers accumulate in the queue without receiving service. Also after completion of the service customer can join the tail of the queue as a feedback customer after a random time for receiving another service with probability r. Otherwise the customer may depart forever from the system with probability 1 - r. By applying the supplementary variables method, we obtain the steady-state solutions for queueing measures. (Received September 16, 2014)

1106-60-2574 **Ke Wang*** (wangk@umn.edu), 306 Lind Hall, 207 Church Street SE, Minneapolis, MN 55455, and **Van Vu**. *Random weighted projections, random quadratic forms and random eigenvectors.*

We start with a simple, yet useful, concentration inequality concerning random weighted projections in high dimensional spaces. The inequality is then used to prove a general concentration inequality for random quadratic forms. In another application, we show the optimal infinity norm $O(\sqrt{\log n/n})$ for most unit eigenvectors of a large class of random matrices of size n, including the adjacency matrix of random graphs. This is joint work with Van Vu. (Received September 16, 2014)

1106-60-2576 **Benjamin Thirey*** (benjamin.thirey@usma.edu) and **Randal E Hickman** (randal.hickman@usma.edu). *Distribution of Distances Between Random Gaussian Points in n-Space.*

The curse of dimensionality is a common phenomenon which affects analysis of datasets characterized by large numbers of variables associated with each point. Problematic scenarios of this type frequently arise in classification algorithms which are heavily dependent upon distances between points, such as nearest-neighbor and k-means clustering. Given that contributing variables follow Gaussian distributions, this research derives the probability distribution that describes the distances between randomly generated points in n-space. A priori understanding of this distribution may help quantify the effect of additional dimensions on the accuracy of statistical learning for some classification problems. The theoretical results are extended to examine additional properties of the distribution as the dimension becomes arbitrarily large. (Received September 16, 2014)

1106-60-2594 **Jebessa B Mijena*** (jebessa.mijena@gcsu.edu), 231 W. Hancock St, Campus Box 17, Georgia College & State University, Milledgeville, GA 31061, and **Erkan Nane** (nane@auburn.edu), 221 Parker Hall, Department of Mathematics and Statistics, Auburn, AL 36849. *Correlation structure of time-changed Pearson diffusions.*

The stochastic solution to diffusion equations with polynomial coefficients is called a Pearson diffusion. If the time derivative is replaced by a distributed fractional derivative, the stochastic solution is called a fractional Pearson diffusion. This paper develops a formula for the covariance function of a fractional Pearson diffusion in steady state, in terms of generalized Mittag-Leffler functions. That formula shows that fractional Pearson diffusions are long-range dependent, with a correlation that falls off like a power law, whose exponent equals the smallest order of the distributed fractional derivative. (Received September 16, 2014)

1106-60-2595 **Adrian D Banner**, **Robert Fernholz**, **Ioannis Karatzas**, **Vasileios Papathanakos** and **Phillip D Whitman*** (pwhitman@intechjanus.com), 1 Palmer Square Ste 441, Princeton, NJ 08542. *Rank-Based Portfolios, the Size Effect, and an Identity for the Exponential Distribution.* Preliminary report.

In an equity market with a stable capital distribution, a capitalization-weighted index of small stocks tends to outperform a capitalization-weighted index of large stocks. This observation is one formulation of the widely noted phenomenon known as the "size effect." We will discuss work that explains this as a portfolio-level effect, beginning with Fernholz (2001). In fact, one can show in a class of models that in fact this outperformance is a necessary consequence of stability properties of the market. Such proofs rely on an understanding of the behavior of collision local times, which are related to the rebalancing of such portfolios. In this talk, we focus on a class of models for which we can show these stability properties are satisfied. Namely, the "Atlas" model, for which one can show the existence of a stable capital distribution, and then obtain a formula for the long-term outperformance for such small stock portfolio with respect to large stock portfolios. As a corollary, we show a novel identity for n independent exponential distributions. *(Joint work with Adrian Banner, Robert Fernholz, Ioannis Karatzas, and Vasileios Papathanakos.)* (Received September 16, 2014)

1106-60-2640 **Ioana Dumitriu*** (dumitriu@uw.edu), University of Washington, Department of Mathematics, BOX 354350, Seattle, WA 98195, and **James Demmel**, **Olga Holtz**, **Grey Ballard** and **Chris Melgaard**. *Randomize to optimize: a brief excursion in the uses of randomness in numerical line algebra algorithms.*

Numerical algorithms strive to be faster, more accurate, parallelizable, communication-optimizing, sparse, dimension-reducing, and so on. More and more often these days, such desirable outcomes are obtained by the introduction of a little randomization. While it may be fathomable that such randomization yields fast results, it is perhaps less intuitive that sometimes it gives outcome guarantees that non-randomized versions of the same algorithm cannot produce. I will describe a few algorithms in which randomization has been of utmost importance, and present a randomized rank-revealing factorization which has a lot of the properties I mentioned above. (Received September 16, 2014)

1106-60-2724 **Barbara H Margolius*** (b.margolius@csuohio.edu), Cleveland State University, Department of Mathematics, 1515RT, 2121 Euclid Ave, Cleveland, OH 44115, and **Malgozata M O'Reilly**, Hobart, Tasmania, Australia. *The analysis of cyclic stochastic fluid flows with time-varying transition rates.*

We consider a stochastic fluid model (SFM) $\{(\widehat{X}(t), J(t)) : t \in \mathbb{R}^+\}$ driven by a continuous-time Markov chain $\{J(t) : t \in \mathbb{R}\}$ with a time-varying generator $T(t)$ and cycle of length 1 such that $T(t) = T(t+1)$ for all $t \geq 0$. We derive theoretical expressions for the key measures for the analysis of the model, and develop efficient methods for their numerical computation. We illustrate the theory with a numerical example. This work is an extension of the results in Bean, O'Reilly and Taylor(2005) for a standard fluid flow model with time-homogeneous generator. (Received September 16, 2014)

1106-60-2726 **Pemantha Lakraj Gamage*** (pemantha.lakraj@ttu.edu), Texas Tech University, Department of Mathematics and Statistics, Broadway and Boston, Lubbock, TX 79409, and **Frits Ruymgaart** (h.ruymgaart@ttu.edu), Texas Tech University, Department of Mathematics and Statistics, Broadway and Boston, Lubbock, TX 79409. *Some Asymptotic Properties of Silverman's Smoothed Functional Principal Components.*

Functional principal components (FPC) reduce dimensionality of infinite dimensional functional data. In many applications, smoothing is necessary when estimating functional principal components. Asymptotic properties of smoothed FPC have many theoretical and practical advantages.

Silverman's (1996) first smoothed FPC is the maximizer over the unit sphere of a quadratic form based on a modified (smoothed) version of the population covariance operator. The sample analogue of the smoothed population covariance operator is close (in probability) to the smoothed population covariance operator, which is in turn close to the original population covariance operator for small values of the smoothing parameter. Perturbation theory can be applied to study asymptotic properties of Silverman's (1996) smoothed FPC.

We define FPC in abstract Hilbert space with properties similar to Silverman's (1996) smoothed FPC. Consistency and asymptotic distributions are derived under mild conditions. We present the result as a simple corollary to general results on the perturbation of eigenvalues and eigenvectors. The rate for this consistency will be obtained. We restrict our attention to the first FPC. However, the same method can be applied to the higher order principal components. (Received September 16, 2014)

1106-60-2740 **Don Gayan Wilathgamuwa*** (don.wilathgamuwa@msubillings.edu), 1500 University Dr, Billings, MT 59101. *Analysis and comparison of stochastic differential equations in population models.*

We summarize the results on existence and uniqueness of solutions to different stochastic differential equation models, and discuss the relations between the models. Also, we compare the persistence time of populations under different models of the form $dX(t) = \mu(t, X(t))dt + \sigma(t, X(t))dB_t$ and $dX(t) = \mu(t, X(t), X(t-T))dt + \sigma(t, X(t), X(t-T))dB_t$, where B_t can be either regular Brownian motion or fractional Brownian motion with Hurst parameter $H > 1/2$. (Received September 16, 2014)

1106-60-2756 **Lu Lu*** (llu@colby.edu), 5830 Mayflower Hill, Waterville, ME 04901. *On the sup-norm of the Bernstein density estimator.* Preliminary report.

Bernstein density estimation is a promising alternative to the traditional kernel method for estimating probability densities with compact support, (e.g., $[0,1]$). The major advantage is that it does not have boundary bias. Here we will study its rate of uniform consistency. In fact, the order of the stochastic error over $[0,1]$ is strictly larger than that over a smaller interval. The result also implies that, for a large class of functions, the Bernstein estimator does not attain optimal rate of convergence under the sup norm. (Received September 16, 2014)

1106-60-2874 **Pallle E. T. Jorgensen** (palle-jorgensen@uiowa.edu), Department of Mathematics, The University of Iowa, Iowa City, IA 52242, and **Myung-Sin Song*** (msong@siue.edu), Department of Mathematics & Statistics, Southern Illinois University Edwardsville, Edwardsville, IL 62026. *Compactification of Infinite Graphs and Sampling.*

We consider Hilbert spaces of functions on infinite graphs and their compactifications. We arrive at a sampling formula in the spirit of Shannon; the idea is that we allow for sampling of functions f defined on a continuum completion of an infinite graph G, sampling the continuum by values of f at points in the graph G. Rather than the more traditional frequency analysis of band-limited functions from Shannon, our analysis is instead based on reproducing kernel Hilbert spaces built from a prescribed infinite system of resistors on G. (Received September 16, 2014)

1106-60-2907 **Umit Islak***, 1267 Fifield Place, St Paul, MN , and **Christian Houdre**. *A Central Limit Theorem for the Length of the Longest Common Subsequence in Random Words.*

Let $(X_k)_{k\geq 1}$ and $(Y_k)_{k\geq 1}$ be two independent sequences of independent identically distributed random variables having the same law and taking their values in a finite alphabet. Let LC_n be the length of longest common subsequences in the two random words $X_1 \cdots X_n$ and $Y_1 \cdots Y_n$. Under assumptions on the distribution of X_1, LC_n is shown to satisfy a central limit theorem. This is in contrast to the limiting distribution of the length of longest common subsequences in two independent uniform random permutations of $\{1,\ldots,n\}$, which is shown to be the Tracy-Widom distribution. (Received September 17, 2014)

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1106-62-21 **Susan Holmes*** (susan@stat.stanford.edu), Statistics Department, Sequoia Hall, 390 Serra Mall, Stanford, CA 94305. *Statistically relevant metrics for heterogeneous data.*

Finding the right distance or dissimilarity solves difficult statistical problems. This talk will provide a survey of mining heterogeneous biological data including networks, trees, images and heteroscedastic variables using weighted dissimilarities and locally defined distances. Carefully tailored "distances" can incorporate prior information on data structure such as hierarchical dependencies between rows of a data matrix or the graph of correlations between the column-variables. Links to differential geometry are useful in incorporating localized information for these complex data structures. Distances are central to the statistical endeavor and enable generalizations of the notions of variance decomposition, nearest neighbor classification and clustering. I will show examples of how these generalizations prove useful in integration of multiple sources of information in the context of the study of the human microbiome. (Received September 15, 2014)

1106-62-93 **Krishan Agrawal***, Department of Mathematics & ComputerScience, Virginia State University, VA 23806, **Ronald Moore**, Performance Polymers, Honeywell, 15801 Woods Edge Road, Colonial Heights, VA 23834, and **Eugene Evans**, Virginia State University. *Determination of the Probability Distribution of strength of a Polymer Fiber Bundle Using Statistical Analysis.*

The purpose of this research is to analyze the randomly selected 21 samples out of 500 samples provided by Performance Materials Technologies Division of Honeywell to investigate relationship between polymer single fiber strength and its bundle. This analysis is done by assuming two parameter Weibull distribution for single fiber strength and the same Weibull distribution for the bundle strength following hierarchical theory. The parameters are estimated using linear regression. It is well known that strength of bundle reduces because of equal load sharing phenomenon as predicted by Daniel's Theory. However, our experimental data shows slight increase in the bundle strength. It seems that this contradiction in theoretical and experimental data results is probably due to high variability in sample data which was confirmed in this study by Tukey's test. This high variability in sample data may be due to chemical process, human error, machine error etc. Therefore in order to find meaningful relationship on the transfer ratio between the strength of single fiber and bundle, more data has to be tested with this approach, also Excel based user friendly program is developed to calculate two parameters of Weibull distribution. (Received September 15, 2014)

1106-62-260 **Rabi Bhattacharya*** (rabi@math.arizona.edu), Department of Mathematics, University of Arizona, Tucson, AZ 85721. *Role of Geometry in Model Independent Statistical inference on Non-Euclidean Spaces.*

This talk focuses on (1) differential geometric depictions of certain classes of digital images arising in biology, medicine, machine vision and other fields of science and engineering and (2) their model-independent statistical analysis for purposes of identification, discrimination and diagnostics. As examples we mention Kendall's landmarks based shape spaces, certain graphical models for evolutionary biology, and the space of diffusion matrices arising in diffusion tensor imaging. Nonparametric inference based on Fréchet means as minimizers of expected squared distances have been recently used effectively for such spaces M, which are either manifolds or stratified spaces. One may use geodesic distances on these spaces under appropriate Riemannian structures, or those induced by embeddings equivariant under the action of a large Lie group on M. We discuss general issues of uniqueness of the Fréchet minimizer and the consistency and asymptotic distribution of its empirical estimate under these distances. The asymptotic dispersion of the intrinsic sample mean is shown to be related to the curvature of M. We also consider the extension of nonparametric Bayesian methods to manifolds for purposes of classification, regression, density estimation. (Received August 16, 2014)

1106-62-295 **Yann Ollivier*** (yann.ollivier@lri.fr), Laboratoire de recherche en Informatique, Université Paris-Sud, Bât. 660, 91405 Orsay, France. *Statistical Learning from Invariance Principles: Robust Algorithms from Information Theory and Riemannian Geometry.*

Statistical learning is the art of discovering complex patterns in data and is an obligatory step towards artificial intelligence. This requires finding good probabilistic models of data and is algorithmically difficult. Moreover, the learning algorithms are often not invariant under simple changes in the representation of data or of intermediate variables of the model, even though this does not change the information present in the data. This lack of invariance introduces many arbitrary choices and makes the results more sensitive to slight changes.

Here we start from invariance principles in a differential-geometric setting, and build Riemannian metrics akin to Fisher's information metric, but more algorithmically scalable. Invariance leads to new learning algorithms which detect more complex patterns and use fewer training samples. We give the example of training recurrent neural networks for detecting grammar-like structures in sequential symbolic data. (Received August 20, 2014)

1106-62-356 **Xavier Pennec*** (xavier.pennec@inria.fr), Inria Sophia-Antipolis, Asclepiosteam, 2004 Route des lucioles, BP93, 06902 Sophia-Antipolis, France. *Riemannian and affine Structures for Geometric Statistics in Computational Anatomy.*

Computational anatomy is an emerging discipline at the interface of geometry, statistics and medicine that aims at analyzing and modeling the biological variability of the organs shapes at the population level. To reach this goal, one needs to design a consistent statistical framework on manifolds and Lie groups. The geometric structure considered so far was that of Riemannian geometry, for instance with (right) invariant metrics on groups of deformations. In parallel, efficient image processing methods based on diffeomorphisms parameterized by stationary velocity fields (SVF) have been developed with a great success from the practical point of view but with less theoretical support.

In this talk, I will detail the Riemannian framework for geometric statistics and partially extend if to affine connection spaces and more particularly to Lie groups provided with the canonical Cartan-Schouten connection (a non-metric connection). In finite dimension, this provides strong theoretical bases for the use of one-parameter subgroups. The generalization to infinite dimensions would grounds the SVF-framework. From the practical point of view, we show that it leads to quite simple and very efficient models of atrophy of the brain in Alzheimer's disease. (Received August 25, 2014)

1106-62-410 **Brice Merlin Nguelifack*** (bmn0003@auburn.edu), 221 Parker Hall, Auburn, AL 36849. *Asymptotics of Signed-Rank Estimator in Two-phase Linear Model.*

In this paper, we considers two-phase random design linear models with arbitrary error densities and where the regression function has a fixed jump at the true change-point. We obtain the consistency, and the limiting distributions of signed-rank estimators of the underlying parameters in these models. The left end point of the minimizing interval with respect to the change point, herein called the R-estimator $\hat{r}_n$ of the change-point parameter r is shown to be n-consistent and the underlying R-process, as a process in the standardized change-point parameter, is shown to converge weakly to a compound poisson process. This process obtains maximum over a bounded interval and $n(\hat{r}_n - r)$ converges weakly to the left end point of this interval. These results are different from those available in the literature for the case of two-phase linear regression models when jump sizes tends to zero as n tends (Received August 27, 2014)

1106-62-638 **Anh V Nguyen*** (anh.v.nguyen@tcu.edu), 3458 Dryden Road Apt 2053, Fort Worth, TX 76109, and **Dana M Lacey** and **Kahadawala Cooray**. *Bathtub and Unimodal Hazard Flexibility Classification of Parametric Lifetime Distributions.*

There are a number of bathtub and unimodal hazard shape parametric lifetime distributions available in literature. Therefore, it is important to classify these distributions based on their hazard flexibility to facilitate their use in applications. For this purpose we use the Total Time on Test (TTT) transform plot with two different criterion: I. measure the slope at the inflection point on the scaled TTT transform curve; II. measure the slope at selected points from the constant hazard line on the scaled TTT transform curve. We confine our research to classify the flexibility of Weibull extensions and generalizations and also select one-shape parameter lifetime distributions to exemplify the two criterion process. (Received September 03, 2014)

1106-62-652 **James D Munyon*** (jdmunyon@student.ysu.edu), 109 North Pearl Street, Columbiana, OH 44408, and **Rebecca M Thiem** (rebecca_thiem@mymail.eku.edu), 6585 Dickey Road, Middletown, OH 45042. *Approaches to Addressing Overfitting in Averaging Classifiers.*

The goal of statistical classification is to learn a model with known data that will accurately predict the class of new cases. Bayesian Model Averaging is theoretically the optimal method for combining learned models, but its application in machine learning remains an open problem due to its tendency to overfit. Overfitting refers to the weight being concentrated on a single or a few models, and results from the exponential form of the weighting function. In this project, we explore a number of alternative weighting schemes in averaging decision trees that aim to address this problem. Our studies show that a movement towards more uniform model weighting yields better results as compared to the previously-mentioned weighting scheme, but that there is still room for improvement in terms of a more accurate model-space approximation. (Received September 04, 2014)

1106-62-803 **Ranil Weerackoon*** (raniljw@yahoo.com) and **Dmitry Suvorov**. *Measures of Predictor Variable Importance in Logistic Regression: A Comparative Study.*

Researchers have often sought to assess the relative importance of predictor variables in a multiple linear regression model. A number of indices of relative importance in multiple linear regression have been proposed in literature, including the squared zero-order correlation, the squared standardized regression coefficient, the product measure (Pratt's index), the squared standardized regression coefficient of y regressed on the least squares orthogonal of the jth predictor, and Johnson's relative weight measure. In this study, we extend these indices to the case of a logistic regression model, when the dependent variable takes a binary form. A Monte Carlo Study is conducted to compare the performance of these indices numerically. Recommendations are made as to which of the relative importance indices are effective for ranking the predictors. (Received September 07, 2014)

1106-62-823 **Persi Diaconis***, Department of Statistics, 390 Serra Mall, Sequoia Hall, Stanford, CA 94305. *From Volume of Tubes to Volume Testing.*

The Hotelling-Weyl Volume of tubes formula is a basic part of differential geometry that was developed for carrying out a statistical test. Mathematically, it gave the first intrinsic description of a variety of higher curvatures. It has been applied in statistics and in probability ever since. I will survey the history and explain one statistical tendril; my work on 'volume testing' with Brad Efron. (Received September 07, 2014)

1106-62-878 **Zhengyi Zhou*** (zz254@cornell.edu), **David S. Matteson**, **Dawn B. Woodard**, **Shane G. Henderson** and **Athanasios C. Micheas**. *A Spatio-Temporal Point Process Model for Ambulance Demand.*

Ambulance demand estimation at fine time and location scales is critical for fleet management and dynamic deployment. We estimate the spatial distribution of ambulance demand in Toronto, Canada, as it changes over discrete 2-hour intervals. This large-scale dataset is sparse at the desired temporal resolutions and exhibits location-specific temporal dependencies. We address these challenges by introducing a novel characterization of time-varying Gaussian mixture models. We fix the mixture component distributions across all time periods to overcome data sparsity and accurately describe Toronto's spatial structure, while representing the complex spatio-temporal dynamics through time-varying mixture weights. We constrain the mixture weights to capture weekly seasonality, and apply autoregressive priors on the mixture weights to represent location-specific serial dependence and daily seasonality. While we can use a fixed number of mixture components, we also extend to estimate the number of components using birth-and-death Markov chain Monte Carlo. The proposed model gives higher statistical predictive accuracy and reduces the error in predicting the industry's operational performance by as much as two-thirds compared to a typical industry practice. (Received September 08, 2014)

1106-62-950 **Anna V. Little*** (alittle2@ju.edu), Department of Mathematics, Jacksonville University, 2800 University Blvd. N, Jacksonville, FL 32211, and **Alicia Byrd**. *A Multiscale Spectral Algorithm for Estimating the Number of Clusters in a Data Set.*

This talk introduces a new multiscale, spectral algorithm for estimating the number of clusters in a data set. Spectral clustering techniques are based on viewing the data as a weighted graph: each data point is a vertex and the weights of the edges are determined by a similarity function. This reduces the clustering problem to a graph cut problem, and an approximate solution can be found by computing the eigenvalues and eigenvectors of the normalized graph Laplacian. Spectral clustering algorithms generally require the user to specify two parameters: the number of clusters k and a scale parameter σ, and the clustering results are very sensitive to these parameter choices. This algorithm computes the eigenvalues of the Laplacian iteratively for a whole range of σ values, and analyzes how these quantities change as a function of the scale σ. Thus variation of the scale parameter, which usually confuses the clustering problem, will actually be used to infer the number of clusters in a robust and automated way. The algorithm is applied to benchmark data sets (both artificial and real-world) for method validation. (Received September 09, 2014)

1106-62-1135 **Mauro Maggioni**, **Stanislav Minsker** and **Nate Strawn*** (nstrawn@math.duke.edu). *Data-driven frames: Non-asymptotic bounds for Geometric Multiresolution Analysis.*

Geometric Multiresolution Analysis (GMRA) was introduced by Allard, Chen, and Maggioni as a computationally efficient procedure for producing robust, multiscale representations of nonlinear data in high-dimensional Euclidean spaces. In this talk, we discuss recent developments which extend the error analysis of GMRA to the class of "noisy" manifolds, a rich and flexible class of data models. In the course of proving these results, we prove explicit bounds for volumes of tubular neighborhoods, bounds which should prove useful for the general statistical theory of manifold learning. (Received September 10, 2014)

1106-62-1406 **Rachel Ward***, rward@math.utexas.edu, and **Yudong Chen**, **Srinadh Bhojanapalli** and **Sujay Sanghavi**. *Coherent matrix completion.*

We show that any n by n matrix of rank r can be exactly recovered from as few as $O(nr\log^2(n))$ randomly chosen elements, provided this random choice is made according to a specific biased distribution based on leverage scores of the underlying matrix. These results simplify and extend previous matrix completion results which rely on certain structural constraints, or incoherences, and the subset of elements is sampled uniformly at random. Our results are achieved by a new analysis based on matrix concentration bounds involving a matrix norm which computes the maximum of appropriately weighted row and column norms of the matrix. Finally, we show how our sampling methods and analysis give rise to new randomized algorithms for computing low-rank matrix approximations, and can provide tighter bounds in terms of the number of computations needed to achieve a certain accuracy in the matrix spectral norm. (Received September 12, 2014)

1106-62-1577 **Netra P Khanal*** (nkhanal@ut.edu), 401 W. Kennedy Blvd, Tampa, FL 33606. *Bayesian Joinpoint Regression Model for Childhood Brain Cancer Mortality.* Preliminary report.

The Bayesian approach of joinpoint regression is widely used to analyze trends in cancer mortality, incidence and survival data. The Bayesian joinpoint regression model was used to study the childhood brain cancer mortality rate and its average percentage change (APC) per year. Annual observed mortality counts of children ages 0-19 from 1969-2009 obtained from Surveillance Epidemiology and End Results (SEER) database of National Cancer Institute (NCI) were analyzed. It was assumed that death counts are probabilistically characterized by the Poisson distribution and they were modeled using log link function. Results were compared with the mortality trend obtained using joinpoint software of NCI. (Received September 14, 2014)

1106-62-1759 **Sonja Petrovic*** (sonja.petrovic@iit.edu), Department of Applied Mathematics, 10 West 32nd Street, room 208, Chicago, IL 60616. *Algebra on hypergraphs with applications to statistics.* Preliminary report.

Social networks and other large sparse data sets pose significant challenges for statistical inference, as many standard statistical methods for testing model/data fit are not applicable in such settings. Algebraic statistics offers a theoretically justified approach to goodness-of-fit testing that relies on the theory of Markov bases and is intimately connected with the geometry of the model as described by its fibers.

Most current practices require the computation of the entire basis, which is infeasible in many practical settings. We present a dynamic approach to explore the fiber of a model, which bypasses this issue, and is based on the combinatorics of hypergraphs arising from the toric algebra structure of log-linear models.

This algebraic statistics problem is intimately tied with graph and hypergraph sampling problems, which will be explained in this setting. Several open problems remain.

This talk will focus on the toric algebra of hypergraphs.

Based on joint work with Elizabeth Gross, Despina Stasi, and others. (Received September 15, 2014)

1106-62-1933 **Talithia Williams*** (twilliams@hmc.edu), 301 Platt Blvd., Claremont, CA 91711. *A Statistician's Guide to Becoming Your Body's Expert.*

The new breed of high-tech self-monitors that measure heart rate, sleep, and steps per day might seem targeted at competitive athletes, all of us should be measuring and recording simple data about our bodies every day. In many ways, our own data can reveal much more than even our doctors may know. Temperature, blood pressure, and heart rate are all forms of data that can help us understand our bodies and recognize when something is going wrong, enabling our doctors to better diagnose us. Since doctors have to work from very generalized data about people's health, we can all benefit from using statistical data to uniquely characterize our body. Personal data can tell a story about your life which can empower you to make better decisions about your personal health. This talk will explore statistical methods surrounding personal data and how data about ourselves that can provide insight into our personal health. (Received September 15, 2014)

1106-62-1963 **Keshav P. Pokhrel*** (kpokhrel@mercyhurst.edu) and **Chris P. Tsokos**. *Modeling Cancer Mortality Rates through Differential Equations.*

Differential equations are powerful tools for modeling data. We present cancer mortality rates as a function of time to explore explicit relation between functions and their derivatives. Nonparametric smoothing methods are used to mitigate the existing randomness in the observed data. We present a systems of differential equations revealing the dynamics of cancer mortality rates in the United States using functional data analysis techniques. This study also present the disparity of brain cancer mortality rates among the age groups together with the rate of change of mortality rates. *Principal Differential Analysis* is used to measure the noisy features of the data in a single curve and the variations of the data are also measured across the curves. (Received September 15, 2014)

1106-62-1994 **Edward J Soares** and **Gopal R Yalla*** (gopal.r.yalla@gmail.com), 47 High Street, Newburyport, MA 01950, and **John B O'Conner**, **Kevin A Walsh** and **Amber M Hupp**. *Hotelling Trace Criterion as a Figure of Merit for the Optimization of Chromatogram Alignment.*

We present a methodology for the optimization of chromatogram alignment using a class separability measure called the Hotelling trace criterion (HTC). In gas chromatography, normal fluctuations occur in peak height due to differences in chemical composition; however, variations in peak location due to measurement error also occur. Without correction along the time axis, analysis of chemical differences could be skewed or obscured. The correlation optimized warping (COW) alignment algorithm was applied to biodiesel data derived from gas chromatography. It requires two input parameters: segment size and maximum warp. The biofuel data, representing classes of soy, canola, tallow, waste grease and a hybrid, were aligned using COW and then transformed into principal components (PC), which were then used to evaluate the HTC. The alignment parameters that maximized the HTC were chosen for our analysis. The results demonstrated that the parameters derived from maximizing the HTC more effectively aligned the data than those derived from other previously published metrics, as evidenced by improved clustering of the classes in the PC-plots. (Received September 15, 2014)

1106-62-2060 **Eric Ruggieri*** (eruggier@holycross.edu), College of the Holy Cross, 1 College Street, Worcester, MA 01610, and **Marcus Antonellis**. *A Bayesian Approach to Sequential Change Point Detection.*

Because long time series are often heterogeneous in nature, the best type of model may be one whose parameters can change through time. The goal of change point analysis is to fit a piecewise regression model to a data set when the set of breakpoints is unknown. The exponential number of possible solutions to a multiple change point problem must be dealt with efficiently if long time series are to be analyzed. Here we introduce a sequential Bayesian change point algorithm that provides uncertainty bounds both on the number and location of the change points in a computationally efficient way. The algorithm is able to quickly update itself as each new data point is recorded and infer whether or not a change point has recently been observed. Simulation studies illustrate how the algorithm performs under various detection criteria and parameter settings, including error rates, detection speeds, and any detection biases. Finally, the Bayesian sequential change point algorithm is used to global surface temperature anomalies over the last 130 years. (Received September 15, 2014)

1106-62-2209 **Paul Bendich**, **J. S. Marron**, **Ezra Miller*** (ezra@math.duke.edu), **Alex Pieloch** and **Sean Skwerer**. *Persistent homology analysis of brain artery trees.*

Persistent homology measures geometric structures using topological invariants. When the structures are magnetic resonance images of arteries in human brains, persistent homology can record connectedness and approximate looping of the blood vessels in these tree-structured objects at multiple scales. Novel approaches to statistical analysis of a population of these brain images result by summarizing the persistence diagrams in various ways, leading to correlations with covariates such as age and sex that are improved relative to earlier analyses of this dataset. (Received September 16, 2014)

1106-62-2803 **Despina Stasi*** (despina.stasi@gmail.com), **Kayvan Sadeghi**, **Alessandro Rinaldo**, **Sonja Petrovic** and **Stephen E. Fienberg**. *The beta model for random hypergraphs with a given degree sequence: modelling multi-way interactions in networks.*

We present a simple and natural class of statistical models for random hypergraphs with a given degree sequence, the beta model for hypergraphs, that allows one to model directly group interactions among individuals in a social network. This model builds upon and generalizes the well-studied beta model for random graphs, which instead considers pairwise interactions. (Received September 16, 2014)

1106-62-2830 **Abbas M Alhakim*** (aa145@aub.edu.lb), American University of Beirut, Bliss Street, P.O.Box: 11-0236, Beirut, Lebanon. *Decomposing the Chi-Square Goodness-of-Fit Statistic by Hadamard-Like Matrices.* Preliminary report.

We present a symbolic decomposition of the Pearson chi-square statistic with unequal cell probabilities, by presenting Hadamard-type matrices whose columns are the eigenvectors of the variance-covariance matrix of the cell counts, with respect to an inner product induced by the cell probabilities. When the latter are equal, this decomposition reduces to a well-known decomposition by regular $\{-1, 1\}$ Hadamard matrices. We also present some natural constructions of eigenvectors for some non-pure powers of 2, for both equal and unequal cell probabilities. (Received September 16, 2014)

65 ► Numerical analysis

1106-65-106 **Hailong Guo***, 1150 Faculty/Administration Building, 656 W. K, Detroit, MI 48202, and **Zhimin Zhang** and **Ren Zhao**. *Hessian Recovery for Finite Element Methods.*

In this article, we propose and analyze an effective Hessian recovery strategy for the Lagrangian finite element method of arbitrary order. We prove that the proposed Hessian recovery method preserves polynomials of degree k+1 on general unstructured meshes and achieve k+1 order superconvergence on mildly structured meshes. In addition, the method is proven to be ultraconvergent (two order higher) for translation invariant finite element space of any order. Numerical examples are presented to support our theoretical results. (Received July 16, 2014)

1106-65-110 **Xiaobing Feng**, **Chiu-Yen Kao** and **Thomas Lewis*** (tllewis3@uncg.edu). *Convergent Finite Difference Methods for Fully Nonlinear Second Order Partial Differential Equations.*

A new framework for designing and analyzing convergent finite difference methods for approximating both classical and viscosity solutions of second order fully nonlinear partial differential equations will be presented. The presented framework will extend the successful framework of monotone, consistent, and stable finite difference methods for first order fully nonlinear Hamilton-Jacobi equations to second order fully nonlinear PDEs such as Monge-Ampère and Bellman type equations. To this end, new concepts of consistency, generalized monotonicity, and stability will be introduced. The main component of the proposed framework is the concept of a "numerical operator", and the main tool for designing methods that satisfy the new framework is the concept of a "numerical moment". These two new concepts play the same roles the "numerical Hamiltonian" and the "numerical viscosity" play in the finite difference framework for first order fully nonlinear Hamilton-Jacobi equations. A class of methods that meets the requirements of the theoretical framework will be defined, and numerical results will be presented to validate the theoretical results. (Received July 17, 2014)

1106-65-186 **Yujie Zhang*** (yjzhang@math.okstate.edu), Oklahoma State University, 401 Math Science, Stillwater, OK 74078. *Weak Galerkin Mixed Finite Element Method for Linear Elasticity Problems.*

In the talk, I will talk about solving linear elasticity problems by using Weak Galerkin mixed finite element method (WG-MFEM), which is a newly developed numerical method for solving partial differential equations. It is shown that WG-MFEM provides an accurate approximation for both the stress tensor and the displacement field of linear elasticity problems. The numerical experiments will be provided to verify that WG-MFEM is efficient and reliable in computing. (Received September 10, 2014)

1106-65-194 **Weizhong Dai*** (dai@coes.latech.edu), Mathematics and Statistics, Louisiana Tech University, Ruston, LA 71272. *Generalized FDTD method for solving Schrodinger equations and open dissipative Gross-Pitaevskii equations.*

In this talk, we present a generalized nite-difference time-domain (G-FDTD) method for solving Schrödinger equations and open issipative Gross-Pitaevskii equations. The idea of this method is first split the unknown function into real and imaginary components resulting in two coupled equations. The real and imaginary components are then approximated using higher-order Taylor series expansions in time and then the derivatives in time are substituted into the derivatives in space via the coupled equations. Finally, the derivatives in space are approximated using higher-order finite difference methods. As a result, the G-FDTD is explicit and permits an accurate solution with simple computation, and also relaxes the stability condition as compared with the original FDTD scheme. The new method is then tested by several examples including soliton propagation and collision,as well as stationary state problem in the non-equilibrium condensate. (Received August 08, 2014)

1106-65-197 **Amanda E Diegel*** (diegel@math.utk.edu), **Steve Wise**, **Xiaobing Feng** and **Cheng Wang**. *Analysis of Mixed FEMs for Cahn-Hilliard-Flow Models.*

Here I present the analysis of both first order and second order (in time) numerical schemes for Cahn-Hilliard-flow equations. The time discretizations are based on a convex splitting of the energy of the equations and we use a continuous Galerkin discretization of space. Our schemes are unconditionally energy stable with respect to a spatially discrete analogue of the continuous free energy of the system and are unconditionally uniquely solvable. Furthermore, we prove that the discrete phase variable is bounded in $L^\infty\left(0,T;L^\infty\right)$ and the discrete chemical potential is bounded in $L^\infty\left(0,T;L^2\right)$, for any time and space step sizes, in two and three dimensions, and for any finite final time T. We subsequently prove that these variables converge with optimal rates in the appropriate energy norms in both two and three dimensions. (Received August 08, 2014)

1106-65-282 **Ioannis Konstantinos Argyros*** (ioannisa@cameron.edu), Cameron University, Department of Mathematical Sciences, 2800 W Gore Blvd., Lawton, OK 73505, and **Daniel González** (daniel.gonzalezs@epn.edu.ec), Escuela Politécnica Nacional, Facultad de Ciencias, Ladrón de Guevara E11-253, 170109 Quito, Ecuador. *Local convergence for an improved Jarratt-type method in anach space.* Preliminary report.

We present a local convergence analysis for an improved Jarratt-type methods of order at least five to approximate a solution of a nonlinear equation in a Banach space setting. The convergence ball and error estimates are given using hypotheses up to the first Fréchet derivative in contrast to earlier studies using hypotheses up to the third Fréchet derivative. Numerical examples are also provided in this study, where the older hypotheses are not satisfied to solve equations but the new hypotheses are satisfied. (Received August 19, 2014)

1106-65-313 **JaEun Ku*** (jku@math.okstate.edu), 401 Mathematical Sceinces, Mathematics, Oklahoma State University, Stillwater, OK 74074. *Efficient two–step hybrid mixed finite element methods.*

A new hybrid mixed finite element method to compute the flux variable accurately and efficiently will be introduced. The method is a two—step method, based on a system of first-order equations for second-order elliptic partial differential equations. On a coarse mesh, the primary variable is approximated by a standard Galerkin method. Then, on a fine mesh, an H(div) projection is sought as an accurate approximation for the flux variable. The computation on a finer mesh can be carried out very efficiently using well developed preconditioners for the H(div) projection. Also, it will be shown that the mesh size h for the finer mesh can be taken as the square of the coarse mesh size H, or a higher order power with a proper choice of parameter. This means that the computational cost for the coarse-grid solution is negligible compared to that for the fine-grid solution. This is a joint work with Dr. Young Ju Lee and Dr. Dongwoo Sheen. (Received August 21, 2014)

1106-65-355 **A M. S. Sayfy*** (sayfy@aus.edu), American University of Sharjah, Department of Mathematics and Statistics, P.O. Box 26666, Sharjah, and **S A Khoury** (skhoury@aus.edu), American University of Sharjah, Department of Mathematics and Statistics, P.O. Box 26666, Sharjah. *Patching strategy for second-order two-point singularly perturbed boundary value problems.*

The aim of this talk is to introduce different patching approaches to solve second-order two-point boundary value problems that possess singularities or layers. For a singularly perturbed problem, the accuracy of some existing methods, deteriorates away from the singularity or the layer . In contrast, some collocation methods are efficient in the absence of singularities or layers.

Our patching approach is based on decomposing the domain into two sub-intervals: a suitable method is implemented in the vicinity of the boundary layer while in the outer region the problem is tackled by an adaptive cubic spline collocation scheme, which includes the use of redistribution functions or constructed grading functions in case the location of the layer is unknown. Numerical results, computational comparisons, appropriate error measures and illustrations are provided to testify the convergence, efficiency and applicability of the approach.

The adaptive patching strategy could be extended to solve time-dependent problems with moving boundary layers and this is worth further investigation. The scope of our current and future work will focus also on embedding Green's function into fixed point iteration schemes to handle these types of problems. (Received August 25, 2014)

1106-65-368 **Marina Moraiti*** (`mmoraiti@gmail.com`), The Dietrich School of Arts and Sciences, 301 Thackeray Hall, Pittsburgh, PA 15260. *Coupled groundwater-surface water flow: effect of small parameters and numerical methods.*

We study the effect of small parameters in the fully evolutionary Stokes-Darcy problem that models the interaction between groundwater and surface water flows. In particular, we look at the effect of the specific storage parameter as it approaches zero as well as at its effect, along with the hydraulic conductivity parameter, on stability and convergence properties of numerical schemes. Further, we present a new numerical method for the coupled problem that is strongly stable - uniformly in all parameters - and second order convergent in space and time. (Received August 25, 2014)

1106-65-381 **Paul Eloe*** (`peloe1@udayton.edu`) and **Yuchen Zhou**. *Pricing Multi-Asset American Options with Regime-Switching by Exponential Time Differencing Schemes.*

This paper is concerned with multi-asset American option pricing problems with regime-switching. It is well known that multi-asset American option prices can be modeled by higher dimensional generalizations of the original Black-Scholes equation. Due to regime coupling, this problem gives rise to a class of complex PDE systems with free boundary conditions. We first apply the penalty method approach to convert the free boundary value PDE system to a system of PDEs over a fixed domain for the time and spatial variables. Then the exponential time differencing Crank-Nicolson (ETD-CN) method is employed to solve the resulting system. In the case of two uncorrelated underlying assets, we establish an upper bound condition for the time step size and prove that under this condition the option values generated by the ETD-CN scheme satisfy a discrete version of the positivity constraint. In addition, we numerically compare the ETD-CN scheme with two other methods, namely the binomial tree method and the implicit penalty method. At the end of this paper, we numerically illustrate the second order convergence of the ETD-CN scheme without theoretical proof. (Received August 26, 2014)

1106-65-397 **Jari Toivanen*** (`toivanen@stanford.edu`). *Operator splitting methods for pricing options under jump-diffusion models.*

The price of a European option can be obtained by solving a partial integro-differential equation (PIDE) under a jump-diffusion model like Merton's model or Kou's model. For an American option the price can be obtained by solving a linear complementarity problem (LCP) with the same one-dimensional parabolic partial integro-differential operator.

Here we discuss operator splitting methods for PIDEs and LCPs. We describe a second-order accurate implicit-explicit (IMEX) method for efficiently treat the integral operator. For American options an easy-to-implement operator splitting method is described for LCPs. Numerical experiments are presented to illustrate the efficiency of the discussed splitting schemes. (Received August 26, 2014)

1106-65-402 **Michelle Craddock Guinn*** (`michelle.guinn@belmont.edu`), 1900 Belmont Blvd, Nashville, TN 37212. *Algorithm to Enhance Stereoscopic Imagery.* Preliminary report.

The objective of my research is to design an algorithm to present enhanced stereoscopic imagery that is adapted to the viewing distance of the observer, with seamless transitions among stereo and hyperstereo levels. I will design an algorithm that use the image smoothing techniques to provide this enhancement. The research will improve images that Soldiers can use to perform several tasks and can potentially provided better situational awareness. (Received August 27, 2014)

1106-65-472 **Ying Li*** (yli@francis.edu), Department of Mathematics, Saint Francis University, Loretto, PA 15940. *Inverse Scattering Approach on Tomography Problem Using Multi-frequency Problem.*

An inverse scattering problem is formulated for reconstructing optical properties of biological tissues. A recursive linearization algorithm is used to solve the inverse scattering problem. We employed the idea of finite element boundary integral method and added suitable boundary conditions on the surface of the domain. The initial guess is obtained by Born approximation based on the fact of weak scattering. The reconstruction is then improved each time by an increment on wave number. Finite element method is used for the interior domain containing inhomogeneity. Nystrom method is used for setting up the boundary conditions and jump conditions. Two numerical examples are presented. (Received August 29, 2014)

1106-65-492 **Emmanuel Asante-Asamini*** (eoa@uwm.edu), Department of Mathematical Sciences, University of Wisconsin-Milwaukee, Milwaukee, WI 53201-0413, **Abdul Q.M. Khaliq** (abdul.khaliq@mtsu.edu), Department of Mathematical Sciences, & Center for Computational Science, Middle Tennessee State University, Murfreesboro, TN 37132, and **Bruce A. Wade** (wade@uwm.edu), Department of Mathematical Sciences, University of Wisconsin-Milwaukee, Milwaukee, WI 53201-0413. *A Real Rational Poles Exponential Time Differencing Scheme for Nonlinear Advection-Diffusion-Reaction Systems.*

A second order Exponential Time Differencing (ETD) method for advection-diffusion-reaction systems which uses a real rational pole discretization method for the underlying matrix exponentials is developed. The method is proven to be stable and second order convergent. Through numerical experiments it is demonstrated to be highly efficient. We discuss several advantages over competing second order schemes, and develop examples using operator splitting in several space dimensions to confirm empirically the effectiveness of the proposed scheme. (Received August 30, 2014)

1106-65-607 **Weiming Cao*** (weiming.cao@utsa.edu), Dept. of Mathematics, The University of Texas at San Antonio, San Antonio, TX 78249. *A Superconvergence Analysis of the Quadratic Finite Element Method Based on Unstructured Anisotropic Meshes.* Preliminary report.

For problems exhibiting strong anisotropic features, the finite element method based on adaptive anisotropic meshes can be much more effective than the one based on isotropic meshes. In this talk, we present our recent results on the error estimates and mesh refinement controls for the anisotropic finite element method. We discuss in particular the quadratic finite element method for two dimensional elliptic equations based on a class of unstructured anisotropic meshes that are quasi-uniform under given Riemannian metrics. Based on the notion of approximate (anisotropic) parallelograms for element pairs and the notion of anisotropic measures for the higher order derivatives of PDE solutions, we show that the finite element solutions are super-close to the the quadratic interpolation of the exact solutions in the energy norm. Numerical results demonstrating the superconvergence behaviors of the adaptive finite element solutions are also presented. (Received September 03, 2014)

1106-65-648 **Samir kumar bhowmik*** (bhowmiksk@gmail.com), Department of Mathematics, Al Imam Mohammad Ibn Saud Islamic University, Riyadh, Saudi Arabia. *Fast and Efficient Numerical Methods for an Extended Black-Scholes Model.* Preliminary report.

An efficient linear solver plays an important role while solving partial differential equations (PDEs) and partial integro-differential equations (PIDEs) type mathematical models. In most cases, the efficiency depends on the stability and accuracy of the numerical scheme considered. In this article we consider a PIDE that arises in option pricing theory (financial problems) as well as in various scientific modeling and deal with two different topics. In the first part of the article, we study several iterative techniques (preconditioned) for the PIDE model. A wavelet basis and a Fourier sine basis have been used to design various preconditioners to improve the convergence criteria of iterative solvers. We implement a multigrid (MG) iterative method. In fact, we approximate the problem using a finite difference scheme, then implement a few preconditioned Krylov subspace methods as well as a MG method to speed up the computation. Then, in the second part in this study, we analyze the stability and the accuracy of two different one step schemes to approximate the model. (Received September 04, 2014)

1106-65-664 **Roger Telschow*** (telschow@mathematik.uni.siegen.de), Geomathematics Group, Walter-Flex-Str. 3, 57068 Siegen, Germany. *A Regularized Orthogonal Matching Pursuit for Geoscientific Inverse Problems.*

We propose an algorithm for the stable solution of inverse problems as they appear in geosciences. Based on an orthogonal matching pursuit, the unknown signal is expanded in terms of trial functions which are iteratively picked from a large redundant set of spherical functions. As a big advantage, the method is able to combine arbitrary spherical basis functions. In particular, we combine spherical harmonics of low degrees with wavelets of different scales and/or scaling functions for the reconstruction of global trends and regional details, respectively. In order to stabilize the solution, we use a Tikhonov regularization with a particular spherical Sobolev norm. Since there is no need to solve any system of equations or any integration problem, the method also provides the ability to handle very large amounts of data or extremely scattered data sets. The outcome is a smooth and sparse approximation of the signal which is locally adapted to the detail structure of the signal as well as to the density of the data. Moreover, in the case that wavelets are contained in the dictionary, we additionally obtain a multiresolution of the signal. Several numerical experiments are presented, e.g., the problem of downward continuation of the gravitational field. (Received September 04, 2014)

1106-65-699 **Xiaoyue Luo*** (xluo@linfield.edu), 900 SE Baker St, McMinnville, OR 97128. *Application of generalized local regularization to an inverse problem in option pricing.*

We investigate the application of the recently developed generalized local regularization theory to a financial problem in option pricing. Our goal is to determine the volatility function from noisy call option prices. This is an important problem not only in theory but also for practitioners working in the financial world. However, there is simply not enough market data available to uniquely determine the value of the volatility function. Moreover, the solution of underlying functional does not depend continuously on the data. Consequently the problem of determining the volatility function is ill-posed. However, well-known regularization methods such as Tikhonov requires an appropriate a-priori guess of the volatility which may not be applicable in practice. To overcome these difficulties, we apply generalized local regularization method and show that our method does not require any a-priori estimate of the volatility. In addition, unlike other classical regularization methods, our method retains the causal structure of the original problem and allows for fast sequential numerical solution. We also give a parameter selection strategy coupled with our regularization method. Finally, we use examples to verify the effectiveness of our method. (Received September 04, 2014)

1106-65-704 **Somayeh Mashayekhi*** (sm2395@msstate.edu), 21 Ace Ave, Apt # 8305, Starkville, MS 39759. *Solving of fractional order differential equations by using hybrid function.*

In this work, a new numerical method for solving the fractional differential equations is presented. The method is based upon hybrid functions approximation. The properties of hybrid functions consisting of block-pulse functions and polynomials are presented. The Riemann-Liouville fractional integral operator for hybrid functions is introduced. This operator is then utilized to reduce the solution of the initial and boundary value problems for fractional differential equations to a system of algebraic equations. Illustrative examples are included to demonstrate the validity and applicability of the technique. (Received September 04, 2014)

1106-65-789 **Jean-Luc Guermond***, Department of mathematics, TAMU, College Station, TX 77843-3368. *Approximation by continuous finite elements of invariant sets of hyperbolic systems.*

Some properties of continuous finite elements to approximate invariant sets of hyperbolic systems are investigated. In the first part of the talk it is shown that it is possible to construct a second-order, explicit, maximum principle satisfying, Lagrange finite element method for solving nonlinear scalar conservation equations. The technique is based on a graph Laplacian viscous bilinear form, a high-order entropy viscosity method, and the Boris-Book-Zalesak flux correction technique. The algorithm works for arbitrary meshes in any space dimension and for all Lipschitz fluxes. A priori error estimates are proved for BV initial data. The formal second-order accuracy of the method and its convergence properties are tested on a series of linear and nonlinear benchmark problems.

The technique is extended to the shallow water equations and the compressible Euler system in the second part of the talk. It is shown in these cases that some important positivity properties can be preserved by the method: height of the water, density, internal energy. A minimum principle of the entropy is also investigated. This work is done in collaboration with B. Popov (Texas A&M). (Received September 06, 2014)

1106-65-860 **Sarah Jane Hamilton*** (sarah.hamilton@marquette.edu), Cudahy Hall, 355, P.O. Box 1881, Milwaukee, WI 53201-1881. *Pulmonary imaging using Electrical Impedance Tomography with a Direct D-bar Admittivity Method.* Preliminary report.

Electrical Impedance Tomography (EIT) is a non-invasive imaging modality in which harmless currents are applied on electrodes placed at the surface of a body, and the resulting voltages are measured. From these surface electrical measurements, one recovers the internal conductivity and permittivity (admittivity) of the body and forms images that a doctor can use for diagnostic/evaluative purposes. EIT is of particular interest for pulmonary imaging of patients in the ICU on respirators and provides a noninvasive bedside assist for medical professionals to monitor and evaluate proper air volume in the lungs as both over and under inflation are detrimental to the patient. The reconstruction task is a highly ill-posed nonlinear inverse problem, which is highly sensitive to noise, and requires the use of regularized solution methods such as the D-bar method. The D-bar method is based on a tailor made scattering transform, a nonlinear Fourier transform, which solves the inverse problem uniquely. In this talk, we discuss the expansion of D-bar methods from conductivity only imaging, to permittivity imaging. Internal conductivity and permittivity reconstructions from experimental tank and human chest EIT measurements are presented. (Received September 08, 2014)

1106-65-1049 **Harish P. Bhatt*** (hpb2e@mtmail.mtsu.edu), 2850 Middle Tennessee Blvd. Apt # D12, Murfreesboro, TN 37130, and **Abdul Q. M. Khaliq** (abdul.khaliq@mtsu.edu). *The Locally Extrapolated Exponential Time Differencing LOD Scheme for Multidimensional Reaction-Diffusion Systems.*

In this paper, a local extrapolation of first order locally one-dimensional exponential time differencing scheme is introduced for numerical solution of multidimensional nonlinear reaction-diffusion systems. This novel scheme has the benefit of solving multidimensional problems in locally one dimensional fashion by implementing sequences of tridiagonal matrix solvers instead of solving a band system. The storage size needed for solving systems in higher dimensions with this scheme is similar to that needed for one spatial dimension systems. Stability analysis shows that the scheme is strongly stable and is particularly beneficial to nonlinear partial differential equations with irregular initial data or discontinuity involving initial and boundary conditions due to its ability to damp spurious oscillations caused by high frequency components in the solution. The order of convergence of the scheme is examined numerically and found to be second order accurate in both time and space. To investigate the performance of the novel scheme, we tested it on a three-dimensional enzyme kinetics of Michaelis-Menten type, two and three-dimensional Brusselator system and two-dimensional Schnakenberg model. The numerical experiments showed that the new scheme is efficient and reliable. (Received September 12, 2014)

1106-65-1137 **Palle Jorgensen***, Palle Jorgensen, math, University of Iowa, Iowa City, IA 52242. *Multiresolutions.*

Multi-scale analyses and multiresolutions in multivariate signal analysis offer fast algorithms which also have strong localization properties. The latter feature makes them useful as wavelet algorithms as well; i.e., for building recursive basis constructions from lter banks and multi-resolutions in Hilbert spaces, yielding much better pointwise approximation properties than traditional Fourier bases. In the talk we present a new approach to subdivision of signals into frequency bands, applicable to modern-day wireless transmission. We present a representation theoretic framework for perfect reconstruction lter-banks: via a representation theory create the Hilbert spaces H, and subspaces in H, in such a way that "non-overlapping frequency bands" correspond to orthogonal subspaces in H; or equivalently to systems of orthogonal projections. Different frequency bands must exhaust the signals for the entire system, the orthogonal projections add to the identity operator in H. We select special families of commuting orthogonal projections in H via an iteration of the initial generators and repeated subdivision sequences. (Received September 11, 2014)

1106-65-1155 **Martin Gutting*** (gutting@mathematik.uni-siegen.de), Geomathematics Group, Emmy-Noether-Campus, University of Siegen, Walter-Flex-Str. 3, 57072 Siegen, Germany. *Parameter Choices for Fast Multipole Accelerated Spline Approximation.*

The Runge-Walsh approximation allows the construction of the solution of boundary value problems in geoscience in terms of harmonic splines. Moreover, due to their localizing properties regional modeling or the improvement of a global model is possible. Fast multipole methods have been developed for some cases of the occurring kernels to obtain a fast matrix-vector multiplication with linear numerical effort. The application of the fast multipole method to approximating splines that also allow the treatment of noisy data requires the choice of a smoothing parameter. We investigate different methods to (ideally automatically) choose this parameter with and without prior knowledge of the noise level. Thereby, the performance of these methods is considered for white as well as colored noise. It should be pointed out that due to the localizing nature of the splines this can be seen as local regularization. Applications to gravitational field modeling and spherical denoising are presented as well as the extension to boundary value problems where the boundary is the known surface of the Earth itself. (Received September 11, 2014)

1106-65-1222 **Bubacarr Bah*** (bah@math.utexas.edu), **Luca Baldassarre** and **Volkan Cevher**. *Model-based Sketching and Recovery with Expanders.*

Linear sketching and recovery of sparse vectors with randomly constructed sparse matrices has numerous applications in several areas, including compressive sensing, data stream computing, graph sketching, and combinatorial group testing. This paper considers the same problem with the added twist that the sparse coeficients of the unknown vector exhibit further correlations as determined by a known sparsity model. We prove that exploiting model-based sparsity in recovery provably reduces the sketch size without sacrificing recovery quality. In this context, we present the model-expander iterative hard thresholding algorithm for recovering model sparse signals from linear sketches obtained via sparse adjacency matrices of expander graphs with rigorous performance guarantees. The main computational cost of our algorithm depends on the difficulty of projecting onto the model-sparse set. For the tree and group-based sparsity models we describe in this paper, such projections can be obtained in linear time. Finally, we provide numerical experiments to illustrate the theoretical results in action. (Received September 11, 2014)

1106-65-1300 **Scott N. Walsh*** (scott.walsh@ucdenver.edu) and **Troy Butler**. *Optimizing Quantities of Interest in High Dimensions to Improve Solutions to Inverse Problems.*

The predictive capabilities of physics-based models are improved by reliably decreasing the size of the sets defining the uncertain input parameters. These sets are often inferred by solution to an inverse problem. We explore techniques for identifying the optimal quantities of interest within a high dimensional output data set for use in the inverse problem to improve the predictive capabilities of a model. Numerical results on physically relevant models are provided. (Received September 12, 2014)

1106-65-1302 **Josh Padgett*** (josh_padgett@baylor.edu) and **Qin Sheng**. *An Exploration of the Exponential Splitting.* Preliminary report.

Exponential splitting methods have been widely utilized for computing numerical solutions of partial differential equations. Different types of error estimates for the splitting procedures have been introduced and studied. In this talk, we will present an improved, new global error analysis for key exponential splitting formulations based on the commutativity of matrix exponentials resulting from different exponential splitting formulas. Computational examples will be provided to illustrate our theoretical results and expectations. (Received September 12, 2014)

1106-65-1376 **Wing Tat Leung***, Department of Mathematics, Texas A&M University, College Station, TX 77843, **Yalchin Efendiev** (efendiev@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77845, and **Eric Chung**. *Multiscale model reduction using Discontinuous Generalized Multiscale Finite Element Methods.*

Due to the complex nature, direct numerical simulations on the fine grid are prohibitively expensive. It is therefore important to develop efficient and accurate methods that allow the use of coarse grids. We present a multiscale finite element method on a coarse grid. The proposed method is based on the Generalized Multiscale Finite Element Method (GMsFEM). To construct multiscale basis functions, we start with two snapshot spaces in each coarse-grid block where one represents the degrees of freedom on the boundary and the other represents the degrees of freedom in the interior. These local spectral problems are different from each other and their formulations are based on the analysis. Using the dominant modes from local spectral problems, multiscale basis functions are constructed to represent the solution space locally within each coarse block. These multiscale basis functions are coupled via the symmetric interior penalty discontinuous Galerkin method. Our methods' stability and spectral convergence are rigorously analyzed. For flow problems, we derive a-posteriori error estimates and develop an adaptive enrichment algorithm. (Received September 12, 2014)

1106-65-1393 **Melvin Leok*** (mleok@math.ucsd.edu), 9500 Gilman Drive #0112, UCSD Mathematics, La Jolla, CA 92093-0112, and **Joe Salamon** and **John Moody**. *Space-Time Finite-Element Exterior Calculus and Variational Discretizations of Gauge Field Theories.*

Many gauge field theories can be described using a multisymplectic Lagrangian formulation, where the Lagrangian density involves space-time differential forms. While there has been prior work on finite-element exterior calculus for spatial and tensor product space-time domains, less has been done from the perspective of space-time simplicial complexes. One critical aspect is that the Hodge star is now taken with respect to a pseudo-Riemannian metric, and this is most naturally expressed in space-time adapted coordinates, as opposed to the barycentric coordinates that Whitney forms are typically expressed in terms of.

We introduce a novel characterization of Whitney forms and their Hodge dual with respect to a pseudo-Riemannian metric that is independent of the choice of coordinates, and then apply it to a variational discretization of the covariant formulation of Maxwell's equations. Since the Lagrangian density for this is expressed in terms of the exterior derivative of the four-potential, the use of finite-dimensional function spaces that respects the de Rham cohomology results in a discretization that inherits the gauge symmetries of the continuous problem. This yields a variational discretization that exhibits a discrete Noether's theorem. (Received September 12, 2014)

1106-65-1397 **Ashley A. Prater*** (ashley.prater.3@us.af.mil). *Source separation of undersampled composite signals via the Dantzig selector.*

The separation of composite signals is a challenging problem with applications in diverse fields such as medical imaging, audio coding, radar remote sensing and atmospheric spectroscopy. Achieving the recovery and separation of the individual components of a composite signal is even more challenging when only a noisy linearly undersampled signal is available for the decoder. However, if the component signals are sparse relative to sufficiently incoherent bases then accurate recovery and separation may be achieved by using the Dantzig selector, a statistical approach to finding a solution to noisy linear regression problems by minimizing the ℓ_1 norm of candidate vectors while constraining the residuals.

In this talk, one possible model for the separation of noisy linearly undersampled signals based on the Dantzig selector with overcomplete dictionaries will be presented, and an algorithm to approximate the solution using the proximity operator will be discussed. Finally, the results of synthetic and real-world numerical experiments supporting the appropriateness of the model, as well as the speed and accuracy of the algorithm, will presented. (Received September 12, 2014)

1106-65-1537 **Andrei Bourchtein***, Rua Gomes Carneiro 1, Pelotas, 96010-610, Brazil, and **Ludmila Bourchtein**. *A time-splitting scheme for fully compressible atmospheric models.*

The complete atmospheric models contain solutions originated by various physical sources such as the atmosphere compressibility, the deformation effects, the gravity force, and also by the non-inertial forces related to the rotated reference frame. These phenomena have different characteristics of the propagation speed and energy contribution. The acoustic waves are the fastest and have negligible energy contribution, the inertial processes are the slowest and the most valuable in energy spectrum, and the gravity waves occupy the intermediate position.

In this study, we develop a semi-implicit time-splitting scheme for the nonhydrostatic atmospheric model. The acoustic and gravity waves are approximated implicitly, while slow inertial terms are treated explicitly. At each time step, the implicit part of approximation is reduced to three-dimensional elliptic equations solved by multigrid method. Stability analysis of the scheme shows that the time step is restricted only by the maximum velocity of the advection. The performed numerical experiments show the computational efficiency of the developed scheme and accuracy of the predicted atmospheric fields. (Received September 14, 2014)

1106-65-1566 **Eric T. Chung**, **Yalchin Efendiev** and **Guanglian Li*** (lotusli0707@gmail.com). *An adaptive GMsFEM for high-contrast flow problems.*

In this paper, we derive an a-posteriori error indicator for the Generalized Multiscale Finite Element Method (GMsFEM) framework. This error indicator is further used to develop an adaptive enrichment algorithm for the linear elliptic equation with multiscale high-contrast coefficients. We consider two kinds of error indicators where one is based on the L^2-norm of the local residual and the other is based on the weighted H^{-1}-norm of the local residual where the weight is related to the coefficient of the elliptic equation. We show that the use of weighted H^{-1}-norm residual gives a more robust error indicator which works well for cases with high contrast media. The convergence analysis of the method is given. (Received September 14, 2014)

1106-65-1584 **Sergey Voronin*** (sergey.voronin@colorado.edu), 526 UCB, University of Colorado, Boulder, CO 80309-0526, and **Gunnar Martinsson** (per-gunnar.martinsson@colorado.edu), 526 UCB, University of Colorado, Boulder, CO 80309-0526. *Fast algorithms and software for low rank matrix approximation with applications to geotomographical inverse problems.*

Many fundamental problems in geoscience require the solution of linear systems with very large coefficient matrices. In geotomography, where the aim is to construct three dimensional models of wave speed velocities in the Earth's interior, the amount of rows (from earthquake – seismic station pairs) in the matrix and of coordinate system variables in the solution vector are both very large. The resulting matrices for global problems, though sparse, are often several TB in size. In addition, due to the uneven distribution of seismic receivers and the often clustered locations of earthquakes, the matrices in geotomography are inherently ill-conditioned, which makes them well suited for low rank approximation with matrices of much smaller size. In this talk, we present some randomized low rank approximation strategies which have been successfully applied in geotomographical applications. We discuss fast algorithms for low rank approximations and the results of applying these approximations to regularization algorithms. We also present the open source software packages which we have developed. These packages can be used to obtain low rank approximations to matrices of various sizes and are programmed to take advantage of modern day parallel CPU and GPU based computing architectures. (Received September 14, 2014)

1106-65-1670 **Paul G Constantine*** (pconstan@mines.edu), 1500 Illinois St, Stratton Hall, Rm 217, Golden, CO 80211, and **David F Gleich** (dgleich@purdue.edu), Lawson Computer Science Building, 1207, 305 N. University Ave., West Lafayette, IN 47907. *Computing Active Subspaces.* Preliminary report.

Complex models in science and engineering commonly contain functions of several variables, $f(\mathbf{x})$. The active subspace is the span of the first few eigenvectors of the average outer product of the gradient $\nabla f(\mathbf{x})$ with itself. Perturbations in $\mathbf{x}$ along these eigenvectors change f more, on average, than $\mathbf{x}$ perturbations orthogonal to the eigenvectors. Discovering the active subspace can reduce the dimension of parameter studies—e.g., by ignoring directions that change f relatively little—enabling otherwise infeasible computations. We employ non-asymptotic random matrix theory to analyze a Monte Carlo method for discovering the active subspace. With these tools, we try to answer, how many potentially expensive gradient samples are needed to accurately approximate the active subspace? (Received September 14, 2014)

1106-65-1698 **Volker Michel***, Department of Mathematics, University of Siegen, Walter-Flex-Str. 3, 57068 Siegen, Germany. *Melting Glaciers and Rising Sea Level — Some Solved and Unsolved Mathematical Problems Behind a Complex Application.*

Melting glaciers on continental areas cause water mass transports into the oceans and, thus, a rising sea level. While this is a very simple principle, the quantification of the whole phenomenon is connected to a series of mathematical challenges:

(1) Satellites reveal gravitational field changes due to the mass transports, but the data first have to be denoised.

(2) Downward continuing the data from the orbit to the Earth's surface and computing masses out of gravitation are both ill-posed inverse problems.

(3) A decreasing (ice) load on land causes a decompression and a rising of the area. This can be modeled with partial differential equations.

(4) The above problems are linked: The decompression and the uplift also change the gravitational field.

Several methods are known for the described problems. However, the demand for more accurate models and the availability of huge amounts of data with a high precision motivate a revision of some of these methods. In this talk, some first results of a new joint interdisciplinary project with J Frohne (Dortmund), J Kusche and R Rietbroek (Bonn), as well as F-T Suttmeier and R Telschow (Siegen) are presented. (Received September 15, 2014)

1106-65-1711 **Sarah Orzlowski***, Department Mathematics, University of Siegen, Walter-Flex Straße 3, 57068 Siegen, Germany. *Reconstuction of electric currents in spherical geometries from magnetic field data via a regularized best basis algorithm.*

Brain activities can be described via electric signals, i.e. neuronal currents, which induce an electric potential on the scalp measured by electroencephalography and a magnetic field outside the head measured via magnetoencephalography. This problem is similar to problems in geomathematics.

The reconstruction of the neuronal currents from these sets of data is an ill-posed inverse problem, since the radial component of the current cannot be reconstructed. Hence, we decompose the current into suitable functions and analyze the null spaces of the associated operators.

It is now our aim to reconstruct and localize the electric currents in the brain by means of the decomposition and the novel regularized functional matching pursuit algorithm (RFMP), which has been used so far for tomographic inverse problems in geophysics. This algorithm needs an appropriate set of trial functions, the so-called dictionary, which we construct for the particular problem, a regularization term, and a regularization parameter, which has to be chosen wisely in order to obtain a suitable solution. With this algorithm, separate inversions of the EEG and MEG data are conducted primarily, followed by a joint inversion of both data sets. Some numerical results for a test case are demonstrated. (Received September 15, 2014)

1106-65-1740 **Matthew A Beauregard*** (beauregama@sfasu.edu), Math Building 301, Nacogdoches, TX 75962, and **Jurgen Geiser** (juergen.geiser@uni-greifswald.de), Felx-Hausdorff-Str. 6, D-17489, Greifswald, Germany. *Multiproduct Expansions in Application to Singular Partial Differential Equations.*

An extrapolated Peaceman-Rachford-Strang splitting method is designed and examined in application to semidiscretized parabolic partial differential equations. A multiproduct expansion method (MPE) is implemented to improve the order of accuracy beyond second order in time. The numerical analysis of the high order splitting method is further validated and illustrated through numerical experiments of linear and nonlinear partial differential equations. (Received September 15, 2014)

1106-65-1793 **Siu A. Chin*** (chin@physics.tamu.edu), MS 4242, College Station, TX 77843. *High-order Path-Integral Monte Carlo methods for solving many-fermion problems.*

Recent advances in forward, or positive-coefficients splitting algorithms for solving the time-irreversible, Schrodinger equation in imaginary time has greatly accelerated physical calculations range from Density Functional Theory for calculating metallic cluster structures to path-integral Monte Carlo methods for solving the ground state energy of liquid Helium. In this work, we show how high-order forward splitting algorithms can be applied to yield high-order Path-Integral Monte Carlo methods for solving many-fermion problems, despite the fermion-sign problem. Results for quantum dots with up to 20 polarized electrons will be shown. (Received September 15, 2014)

1106-65-1965 **Dalton M Woodard*** (daltonmwoodard@gmail.com) and **Mohamed Moustaoui** (mohamed.moustaoui@asu.edu). *Stability and Accuracy Analysis of a Split-Explicit Scheme based on a Fourth-Order Time-Filtered Leapfrog Method.*

In this talk we analyze the behavior of a new split-explicit numerical scheme combining a semi-implicit scheme with a fourth-order time-filtered Leapfrog method. This new scheme is aimed at numerically stable, accurate, simple, yet efficient numerical integration of certain classes of partial differential equations appearing often in atmospheric, ocean, and climate modeling. In particular our attention will be focused on the ability of this new scheme to accurately resolve physical solutions, while successfully damping unphysical modes. We present an accuracy and stability analysis, noting briefly at first what we mean by numerical stability of schemes. We then offer a comparison in stability between this new scheme, other Leapfrog schemes, and the widely used third-order Runge-Kutta method, making special note of the similarities and, moreover, the computational efficiencies gained over the latter. In conclusion, we consider a solution generated by this new scheme to a common test case of nonlinear atmospheric models, and note its consistency with the canonical solution as an empirical verification of stability. (Received September 15, 2014)

1106-65-2065 **Joseph Eichholz*** (eichholz@rose-hulman.edu). *An adaptive method for the fast numerical solution for the radiative transport equation.*

The radiative transport equation is a hyperbolic integro-differential equation with applications in heat transfer, atmospheric physics, and medical imaging, to name a few. In many applications high dimensionality and tight coupling between angular and spatial variables make the problem quite challenging to solve using existing numerical methods. In this talk we introduce two new error a-posteriori error estimates for numerical approximations to solutions of the RTE. We subsequently derive an adaptive method and demonstrate its effectiveness in cases of practical interest. (Received September 15, 2014)

1106-65-2099 **Fred J Hickernell*** (hickernell@iit.edu), Department of Applied Mathematics, E1-208, Illinois Institute of Technology, 10 W. 32nd Street, Chicago, IL 60616. *Adaptive Algorithms for Computing Expectations and Integrals.*

Most adaptive algorithms have no guarantees of success. Most algorithms with theoretical underpinnings are not adaptive. Here we present recent work to develop algorithms that compute the means of random variables and the integrands of univariate and multivariate functions. These algorithms are adaptive, meaning that the amount of computational work required depends on the difficulty of the problem. They are also guaranteed to succeed for random variables or integrands satisfying certain cone conditions. (Received September 15, 2014)

1106-65-2135 **Edward W. Swim***, Department of Mathematics and Statistics, Box 2206, Huntsville, TX 77341, and **Stephen M. Scariano**, Department of Mathematics and Statistics, Box 2206, Huntsville, TX 77341. *Piecewise Polynomial Approximations to the Standard Normal Cumulative Distribution Function.*

Many efforts have been made to approximate the standard normal distribution, using a form that is simpler in some sense than the integral definition of the normal cumulative distribution function (CDF), for both numerical and educational purposes. Many of these approximations suffer from inaccuracy in common intervals of interest and/or include functions that require an understanding of transcendental functions to calculate the probability density function. Piecewise polynomial interpolation provides an effective method for approximation that may somewhat retain the shape of the CDF and yet require only a basic understanding of polynomials for further analysis. Here we present piecewise polynomial approximations to the standard normal CDF with a closed form representation that is easily manipulated by undergraduate students who lack significant exposure to calculus.

Simultaneously, our approximations provide a high degree of accuracy on even the widest intervals of common use in most areas of application. (Received September 15, 2014)

1106-65-2189 **Wenbin Chen** (wbchen@fudan.edu.cn), **Max Gunzburger** (gunzburg@fsu.edu), **Dong Sun*** (dsun@math.fsu.edu) and **Xiaoming Wang** (wxm@math.fsu.edu). *One Type of Efficient and Long-Time Accurate Third-Order Method for the Stokes-Darcy System.*

We propose and study one type of third-order in time implicit-explicit (IMEX) method for the coupled Stokes-Darcy system, which is commonly used in the modeling of the flow in karst aquifers and other subsurface flows. The method is a combination of the third-order Adams-Moulton and third-order Adams-Bashforth methods. Although the model is coupled on the continuous level, the numerical algorithm is fully-decoupled, i.e., we only need to solve a decoupled Stokes equation and a decoupled Darcy equation at each time step. Therefore, the scheme is very efficient, and can be computed in a parallel fashion using legacy codes. The unconditional and uniform in time stability for the scheme is proved. The uniform in time stability provides uniform in time control of the error which is very important for many physical processes that happens over a large period of time, e.g., contaminant accumulation and transport. Error estimate for the semi-discretized scheme is derived. Numerical examples are tested to illustrate the accuracy, efficiency, and long-time stability of the the scheme. (Received September 16, 2014)

1106-65-2198 **Gregory T Minton*** (gminton@alum.mit.edu). *Knotted Field Lines and Computer-Assisted Proof.*

Problem 18 in *The Scottish Book* asks whether magnetic field lines can be knotted; more specifically, the problem is to find a knotted simple closed curve such that, when current flows through it, the generated magnetic field has a field line which is also a knotted simple closed curve. We will demonstrate the existence of such knots by showing concrete, albeit non-explicit, examples. In addition to being knotted, these examples exhibit qualitatively different behavior from the simplest cases of magnetic field lines generated by linear current.

Our results were obtained numerically and then proven using computer-assisted proof techniques. This procedure can be understood as a rigorous spectral method for proving the existence of periodic solutions of ODEs. After presenting our results on Problem 18, we will outline this method of computer-assisted proof, show some other applications of the proof techniques, and close with some directions for future work. (Received September 16, 2014)

1106-65-2211 **Dongming Wei***, 6204 Wadsworth Drive, New Orleans, LA 70122. *Nonlinear Waves Arising from Modeling of Graphene and Polyimide Structures.* Preliminary report.

In this talk, we present some results in studying nonlinear waves arising from modeling vibrations of springs, rods, and beams made of graphene and polyimide respectively. Analytic solutions of some spring-mass equations are presented in terms of generalized trigonometric functions such as the elliptic-Jacobi functions and some non-Euclidean two parameter sine functions. Numerical analysis and numerical solutions are also presented. (Received September 16, 2014)

1106-65-2236 **Volker Michel***, Department of Mathematics, University of Siegen, Walter-Flex-Str. 3, 57068 Siegen, Germany. *A Greedy Algorithm for the Regularization of Inverse Problems in Geophysics and Medical Imaging.*

A nonlinear approximation method for the regularization of ill-posed inverse problems is presented. It is applicable to inverse problems which are representable by a finite set of linear and continuous functionals (e.g. samples of the right-hand side of a Fredholm integral equation). Problems of this type, in particular in combination with domains which are a sphere or a ball, occur e.g. in the geosciences and in medical imaging. The presented method is based on a Matching Pursuit for data interpolation by Mallat and Zhang and by Vincent and Bengio. The novelties of the approach are: first, inverse problems can be solved (i.e. data and solution can originate from different spaces and may be connected by equations to be solved); second, a regularization term to stabilize ill-posed problems is included; third, in the implementation we use global and localized trial functions (orthogonal polynomials, splines, wavelets etc.) on a ball or a sphere.

The algorithm, which we call the Regularized (Orthogonal) Functional Matching Pursuit (RFMP and ROFMP, resp.) is able to combine the features of different basis systems known from signal analysis. It provides a stable and sparse approximation to the unknown solution. Theoretical properties and numerical results are shown. (Received September 16, 2014)

1106-65-2248 **Yalchin Efendiev*** (efendiev@math.tamu.edu), TAMU 3368, College Station, TX 77845.
Multiscale model reduction for subsurface applications.

Many application problems have multiscale nature. Due to disparity of scales, the simulations of these problems are prohibitively expensive. Some types of upscaling or model reduction techniques are needed to solve many multiscale problems. In this talk, we will discuss a few known techniques that are used for problems with scale separation and focus on Generalized Multiscale Finite Element Method (GMsFEM) that has been recently proposed for solving problems with non-separable scales and high contrast. The main objective of the method is to provide local reduced-order approximations for linear and nonlinear PDEs via multiscale spaces on a coarse computational grid. (Received September 16, 2014)

1106-65-2257 **Mariantonia Cotronei*** (mariantonia.cotronei@unirc.it), DIIES, University of Reggio Calabria, Via Graziella - loc. Feo di Vito, 89135 Reggio Calabria, Italy, and **Milvia Rossini** and **Tomas Sauer**. *A multiple multiresolution analysis for image processing.*

The concept of multiple multiresolution analysis in $L^2(\mathbb{R}^s)$ has recently been introduced as an extension of the classical wavelet setting. In such an approach, each step of the filterbank implementation can be controlled by different scaling matrices and filters chosen from a finite dictionary. Such a strategy allows for a directionally adapted processing of the data which can be used, for example, for the detection of singularities along curves. In this talk, we restrict to the bidimensional case and present a strategy for multiple filterbank construction based on expanding matrices presenting anisotropic properties and very small determinant. This implies a considerable reduction in terms of computational efforts for processing image data, compared with the well-known discrete shearlet transform. After discussing about the filter construction strategy and the slope resolution property of our scheme, we will present a few examples of applications. (Received September 16, 2014)

1106-65-2341 **Matthew Nabity*** (nabitym@wou.edu) and **David Avery**. *Non-partitioned Recognition Algorithm for 2-tree Probe Interval Graphs.* Preliminary report.

Let G be a simple, undirected, finite graph with vertex set $V(G)$ and edge set $E(G)$. A graph G is a probe interval graph if there is a partition of $V(G)$ into P and N and a collection $\{I_v : v \in V(G)\}$ of closed intervals of $\mathbb{R}$ in a one-to-one correspondence with $V(G)$ such that $uv \in E(G)$ if and only if $I_u \bigcap I_v = \emptyset$ and at least one of u or v belongs to P. The set P is referred to as the probes, and the set N the non-probes. Recognition of probe interval graphs has been studied extensively. Recognizing probe interval graphs can be broken down into two types of problems: partitioned and non-partitioned. A partitioned recognition algorithm includes the probe and non-probe partition as part of the input, where a non-partitioned algorithm does not. Because of the difficulty of the non-partitioned problem, many have turned their attention to the recognition of probe interval graphs from specific families of graphs. We present an efficient non-partitioned recognition algorithm for probe interval 2-trees and provide a complexity analysis. (Received September 16, 2014)

1106-65-2409 **Simon Foucart***, foucart@math.uga.edu. *Recovery of signals with sparse frame expansions.*

This talks surveys some recent results on the reconstruction of vectors acquired from a limited number of imperfect measurements in the case where the vectors are known to be sparse or compressible in a frame (not necessarily a tight frame). We focus mainly on inequality-constrained and equality-constrained ℓ_1-minimizations, but iterative greedy algorithms are also considered. In addition, we discuss the extreme quantization scenario where only binary measurements are available. (Received September 16, 2014)

1106-65-2632 **Hanna M Kristensen*** (hanna.kristensen@pepperdine.edu) and **Erika Ordog**.
Applications and mathematical challenges of digital image mosaicking.

We have created an automatic algorithm that creates a mosaic of user-supplied digital images to reproduce a user-supplied single larger digital image. In creating the mosaic of smaller images to reproduce the larger image, the simplest approach in selecting which image to place in each larger image pixel location is simply to select the one image of all smaller images whose overall color or grayscale levels best matches that of the larger image at that pixel location. However, for a higher quality result, other additional considerations and issues arise, including: reshading of the smaller images to better match the color or grayscale value at each large image pixel location; how to best reproduce essentially solid (constant-valued) areas in the larger image; creating more smoothness between smaller images in the mosaic for a more visually pleasing large image; ensuring that all of the smaller user-supplied supplied images are used at least once in reproducing the larger image, or possibly using all of the smaller images essentially an equal number of times; and numerical issues such as image and integer types in working in Matlab. Our work thus far has focused primarily on grayscale images and is the foundation of our ongoing work with color image mosaicking. (Received September 16, 2014)

1106-65-2892 **M. Zuhair Nashed*** (zuhair.nashed@ucf.edu), Department of Mathematics, University of Central Florida, Orlando, FL 32816-1346. *Applications of Sampling Expansions in Inverse Problems and Moment Problems.*

We discuss preliminary ideas on the use of sampling expansions in reproducing kernel Hilbert space in approximations of linear integral equations and operator equations. We also consider moment discretization of operator equations and reconstruction of a function from its moments in this context. (Received September 17, 2014)

68 ► Computer science

1106-68-261 **Amalya Mihnea*** (amalyamy@yahoo.com) and **Mihaela Cardei**. *Analysis of Interference and Scheduling for a Robust Channel Assignment Method in Cognitive Radio Networks.*

Cognitive radio networks (CRNs) are a promising solution to the problem of inefficient spectrum usage. This technology allows primary users (PUs) to share the spectrum with secondary users (SUs), where SUs communicate through unassigned spectrum bands without disrupting the regular usage of the PUs. CRNs allow SUs to take advantage of unoccupied spectrum in an opportunistic manner using dynamic spectrum access strategies. Network interference is an important parameter that affects the performance of a network. By reducing interference, the capacity of the network is improved and this leads to an increased efficiency in communication. The analysis of interference helps us to choose the most efficient parameters for our algorithm and to design appropriate scheduling patterns. This study is an extension to a previous work in which a channel assignment algorithm that is robust to the presence of PUs was introduced. (Received September 12, 2014)

1106-68-322 **Walter O Krawec*** (walter.krawec@gmail.com), Hoboken, NJ 07030. *Security in the Semi-Quantum Setting.*

Semi-Quantum Key Distribution (SQKD) protocols, introduced by Boyer et al. in 2007, allow a fully quantum A and a limited “classical” B to distill a secret key, secure against even an all powerful adversary E. These protocols rely on a two-way quantum communication channel making their security analysis difficult. We proved in [1] that, for certain families of protocols, we need only consider restricted attacks consisting of a bias and a single unitary. We extend this result to prove the security of a new multi-user SQKD protocol we devised (allowing two limited “classical” users, A and B, to distill a secret key with the help of an untrusted quantum server). We compute a lower bound, as a function only of the observed error rate, of this protocol's key generation rate in the asymptotic scenario. Our result demonstrates that the security of a SQKD protocol can be comparable to some “fully” quantum ones, which was an open question.

[1] W.O. Krawec, “Restricted Attacks on Semi-Quantum Key Distribution Protocols”, Quantum Information Processing, 2014, DOI: 10.1007/s11128-014-0802-2 (Received September 03, 2014)

1106-68-371 **Radhakrishnan Balu*** (radhakrishnan.balu.civ@mail.mil), Aberdeen, MD 21005, and **Dale Shires** and **Raju Namburu**. *A quantum algorithm for uniform sampling of models of propositional logic based on non-commutative probability.*

We describe adiabatic quantum annealing algorithms to generate models of propositional logic with equal probability. The algorithms perform quantum diffusion on a binary hypercube and quantum walks on spin chains to evolve the system adiabatically to a ground state that is interpreted as solution for the underlying satisfiability (SAT) problem. We describe the quantum walks using non-commutative quantum probability and discuss results from implementing the algorithms on a quantum annealer. (Received September 15, 2014)

1106-68-1108 **Nicholas J.A. Harvey*** (nickhar@cs.ubc.ca) and **Neil Olver** (n.olver@vu.nl). *Matroid Bases and Matrix Concentration.*

Let x be a point in $[0,1]^m$ and let $M_1,\ldots,M_m$ be real, symmetric matrices of the same size. If we independently sampled $X_i \in \{0,1\}$ with $\mathbb{E}[X_i]=x_i$ then recently developed matrix concentration bounds imply that $\sum_i (X_i - x_i)M_i$ is probably “small”.

Suppose we additionally know that x lies in a matroid base polytope. The independently-sampled point X would typically lie outside this polytope. We show that a dependent sampling process known as “pipage rounding” will produce a vertex Y of this polytope such that $\mathbb{E}[Y_i]=x_i$ and $\sum_i (Y_i - x_i)M_i$ obeys Tropp's matrix concentration bounds, just like in the independent case. This result has applications in spectral graph theory.

The proof of our result involves a new variant of Lieb's concavity theorem in matrix analysis, which may be of independent interest. (Received September 10, 2014)

1106-68-1575 **Mahdi Cheraghchi*** (mahdi@csail.mit.edu), MIT CSAIL, 32 Vassar Street, Cambridge, MA 02139. *Capacity and Constructions of Non-Malleable Codes.*

Non-malleable codes, introduced by Dziembowski, Pietrzak and Wichs (ICS 2010) and motivated by applications in tamper-resilient cryptography, encode messages in a manner so that tampering the codeword causes the decoder to either output the correct message or an uncorrelated message. While this relaxation of error detection is an impossible goal to achieve against unrestricted tampering functions, rather surprisingly non-malleable coding becomes possible against any fixed family of tampering functions that is not too large. The following subjects will be discussed:

1. "Capacity" of non-malleable codes: For any tampering family of a prescribed size, an optimal bound is derived on the maximum possible rate of a non-malleable code against the given family.

2. An efficient Monte-Carlo construction of non-malleable codes against any family of tampering functions of exponential size (e.g., polynomial-sized Boolean circuits) is given.

3. The specific family of bit-tampering adversaries, that is adversaries that independently act on each encoded bit, will be considered. For this family, an explicit construction of non-malleable codes achieving rate arbitrarily close to 1 is discussed.

Based on joint work with Venkatesan Guruswami and articles arXiv:1309.0458, arXiv:1309.1151. (Received September 14, 2014)

1106-68-1641 **Bren Cavallo***, Mathematics Department, CUNY Graduate Center, New York, NY 10016, and **Delaram Kahrobaei** and **Vladimir Shpilrain**. *Decoy-Based Secure Delegation of Computation, With Application to RSA.*

In this talk, I will introduce a method of secure delegation of computation where the security is not based on any computational assumptions, but rather on numerous "decoys". As an application, this method can be used by a computationally weak party to delegate the exponentiation that takes place in the RSA protocol. This is joint work with Delaram Kahrobaei and Vladimir Shpilrain. (Received September 14, 2014)

1106-68-1720 **Yuan Feng*** (yuan.feng@uts.edu.au), **Nengkun Yu** and **Mingsheng Ying**. *Model checking quantum Markov chains.*

Although security of quantum cryptography is provable based on principles of quantum mechanics, it can be compromised by flaws in the design of quantum protocols. So, it is indispensable to develop techniques for verifying and debugging quantum cryptographic systems. Model-checking has proved to be effective in the verification of classical cryptographic protocols, but an essential difficulty arises when it is applied to quantum systems: the state space of a quantum system is always a continuum even when its dimension is finite. To overcome this difficulty, we introduce a novel notion of quantum Markov chain, especially suited for modelling quantum cryptographic protocols, in which quantum effects are encoded as super-operators labelling transitions, leaving the location information (nodes) being classical. Then we define a quantum extension of probabilistic computation tree logic (PCTL) and develop a model-checking algorithm for quantum Markov chains. (Received September 15, 2014)

1106-68-1802 **Ryan Poffenbarger***, poffenbargerrt16@mail.vmi.edu, and **Christopher Siebert**, siebertcm16@mail.vmi.edu. *From Start to Finish: Linux Clusters for Applied Mathematics.*

In this session, we discuss the cadet-built computational cluster "RAT," created for applied mathematics research at the Virginia Military Institute. Repurposing 20 commodity-grade desktop PCs, we constructed a fully-functional, distributed-memory Linux cluster. RAT serves as a practical learning lab for cadets interested in scientific computing at a large scale, replicating supercomputing concepts difficult to explain on a single machine. In concluding this session, we present parallel processing examples in applied mathematics, and their respective benchmarks, to emphasize RAT's strong performance relative to its low cost. (Received September 15, 2014)

1106-68-1835 **Salvador Elias Venegas-Andraca*** (salvador.venegas-andraca@keble.oxon.org), Ap. postal 12-808, 03001 Mexico City, Mexico, Mexico, and **Marco Lanzagorta** (marco.lanzagorta@nrl.navy.mil), 4555 Overlook Ave. SW, Washington, D.C., DC 20375. *Quantum walk-based associative memories.*

Associative memories are mathematical models of computation well suited for data search purposes. Associative memories have been used to design (classical and quantum) pattern recognition algorithms potentially useful in the field of Image Processing, a pervasive and cross-disciplinary field of computer science and engineering that focuses on storing, manipulating and retrieving visual information in computer systems.

The field of quantum walks was born as a quantum-mechanical counterpart of random walks, a branch of Markov processes extensively used for the development of stochastic algorithms. Recently, it has been proved that a universal model for quantum computation can be built upon both continuous and discrete models of quantum walks. Moreover, significant efforts have been made over the last few years to harness the computational properties of quantum walks in theoretical and applied computer science.

In this talk we shall present some preliminary results on the development of quantum walk-based algorithms to store and retrieve patterns on associative memories. This approach is important because it would allow faster pattern recognition and matching in data intensive and noisy applications. (Received September 15, 2014)

1106-68-2232 **Matthew Hirn*** (matthew.hirn@ens.fr), Ecole normale superieure, Departement d'Informatique, 75005 Paris, France, and **Stephane Mallat** and **Nicolas Poilvert**. *High dimensional learning rather than computing in quantum chemistry.*

Physical functionals are usually computed as solutions of variational problems or from solutions of partial differential equations, which may require huge computations for complex systems. Quantum chemistry calculations of molecular ground state energies is such an example. Machine learning algorithms do not simulate the physical system but estimate solutions by interpolating values provided by a training set of known examples. However, precise interpolations may require a number of examples that is exponential in the system dimension, and are thus intractable. This curse of dimensionality may be avoided by computing interpolations in smaller approximation spaces, which take advantage of physical invariants. We introduce deep multiscale learning architectures in a similar vein to deep neural networks, which compute such invariant approximations via iterated wavelet transforms. Theoretical results relating these architectures to the Coulomb potential from classical physics will motivate numerical applications for molecular energies in quantum chemistry, in relation with Density Functional Theory. (Received September 16, 2014)

1106-68-2919 **Hannah Alpert**, **Jesús A. De Loera**, **Susan Margulies**, **Michael Pernpeintner**, **Eric Riedl**, **David Rolnick*** (drolnick@math.mit.edu), **Gwen Spencer**, **Despina Stasi** and **Jonathan Swenson**. *Algebraic algorithms for hard combinatorial problems: Graph coloring.*

A remarkable number of difficult combinatorial problems can be rephrased in terms of polynomial systems, an approach that Alon has termed the "polynomial method". Accordingly, there is great interest in algorithms that find explicit or approximate solutions to combinatorial polynomial systems in a reasonable amount of time. We consider the complexity of finding the chromatic number of a graph by solving an associated system of polynomial equations. We identify graphs for which the method of Gröbner bases yields a fast solution. We also consider the difficulty of proving that the system is infeasible using the Hilbert Nullstellensatz, by providing lower bounds on the minimum degree of a Nullstellensatz certificate. Finally, we show how graph coloring implies that certain problems for Gröbner bases are NP-hard. (Received September 17, 2014)

70 ► Mechanics of particles and systems

1106-70-526 **Ernesto Perez-Chavela*** (epc@xanum.uam.mx), Av. San Rafael Atlixco 186, Col. Vicentina, 09340 Mexico, D.F., Mexico, and **Luis Garcia-Naranjo** and **Juan Carlos Marrero**. *Periodic orbits in spaces of constant negative curvature.* Preliminary report.

We consider N–point positive masses moving on a two dimensional space of constant negative curvature K. Using the cotangent potential as a generalization of the Newtonian one on this space, and the Poincaré upper semiplane model of the hyperbolic geometry, we describe some especial kind of periodic orbits where the mutual distances among the particles remain constant for all time. We classify these orbits called relative equilibria for the case $N = 3$. We also describe some relative equilibria for $N = 4, 5$. (Received September 01, 2014)

1106-70-666 **Skyler C. Simmons*** (xinkaisen@gmail.com) and **Lennard F. Bakker** (bakker@mathematics.byu.edu). *A Separating Surface for the Generalized Sitnikov Problem.*

We consider the a generalization of the Sitnikov problem of Newtonian mechanics. For a periodic, planar configuration of n bodies which is symmetric under rotation by a fixed angle, the z-axis is invariant. We consider the effect of placing a massless particle on the z-axis. The study of the motion of this particle can then be modeled as a time-dependent Hamiltonian System. We give a geometric construction of a surface in phase space separating orbits for which the massless particle escapes to infinity from those for which it does not. The construction is demonstrated numerically in a few examples. (Received September 04, 2014)

1106-70-1041 **Cristina Stoica*** (cstoica@wlu.ca), Department of Mathematics, Wilfrid Laurier University, 75 University Ave. Wesr, Waterloo, Ontario N2L 3C5, Canada. *N-body problems and fluids mechanics.*

It is well known that the N-vortex problem shares many common features with the N-body of celestial mechanics. In this talk I will present other examples of N-point systems which are either simplified or truncated models of fluid motion. These models display similar properties (Hamiltonian structure, continuous symmetries), as inherited from the original fluid system. Also, when present, discrete symmetries allow the study of these N-point systems by employing the same methods. (Received September 09, 2014)

1106-70-1562 **Elizabeth Zollinger*** (ezollinger@sjcny.edu). *Family of Orbits in the Newtonian 3-Body Problem.*

In this talk we give the topology of a family of periodic orbits in the planar Newtonian three body problem, known as "comet" orbits, where one body (the comet) orbits the binary system formed by the other two. The original proof of existence uses the Implicit Function Theorem with the distance between the bodies of the binary pair as the small parameter and hence applies only when the distance is small. By using the Principle of Least Action and variational techniques, we can extend the existence proof of orbits where the comet comes close to the binary pair. All of these orbits have the same topology and they can be deformed into each other without passing through collision. (Received September 14, 2014)

1106-70-1836 **Martha Alvarez-Ramirez*** (mar@xanum.uam.mx), Departamento de Matematicas. UAM-Iztapalapa, Col. Vicentina. Iztapalapa, 09340 Mexico D.F., Mexico. *Transport orbits in an equilateral restricted four–body problem.*

In this talk we consider a restricted equilateral four-body problem where a particle of negligible mass is moving under the Newtonian gravitational attraction of three masses (called *primaries*) which move on circular orbits around their center of masses, such that their configuration is always an equilateral triangle (Lagrangian configuration). We consider the case of two bodies of equal mass, which in adimensional units is the parameter of the problem. We study numerically the existence of families of unstable periodic orbits, whose invariant stable and unstable manifolds are responsible of the existence of homoclinic and heteroclinic connections, as well as, of transit orbits traveling from and to different regions. We explore, for three different values of the mass parameter, what kind of transits and energy levels exist for which there are orbits with prescribed itineraris visiting the neighborhood of different primaries. This is joint work with Esther Barrabés. (Received September 15, 2014)

1106-70-2663 **A. Bass Bagayogo*** (abagayogo@ustboniface.ca), 200 Avenue de la Cathedral, Winnipeg, Manitoba R2H 0H7, Canada. *Granular Flows Based on Discrete Element Method Modeling.*

Physical processes that involve the disaggregation and movement of material like Granular Material (GM) are best modeled with Discrete Element Method (DEM) rather than continuum methods such as finite elements. In this talk, after a short overview of the mathematical challenges and the state of the art related to the diverse set of behaviors of GM, I will present some numerical simulations results by using the Discrete Element Method (DEM) in order to simulate a wide variety of certain particle shapes such as spheres or ellipses. Discrete element methods are relatively computationally intensive, which limits either the length of a simulation or the number of particles. Several DEM codes, as do molecular dynamics codes, take advantage of parallel processing capabilities to scale up the number of particles or length of the simulation. (Received September 16, 2014)

74 ► Mechanics of deformable solids

1106-74-150 **Tina Mai*** (mai@math.tamu.edu), Department of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77843-3368, and **Jay R. Walton** (jwalton@math.tamu.edu). *On Monotonicity for Strain-Limiting Theories of Elasticity.*

This presentation addresses certain notions of convexity for strain-limiting theories of elasticity in which the Green-St.Venant strain tensor is written as a nonlinear response function of the second Piola-Kirchhoff stress tensor. Previous results on strong ellipticity for special strain-limiting theories of elasticity required invertibility of the Fréchet derivative of the response function as a fourth-order tensor. The present contribution generalizes the theory to cases in which the Fréchet derivative of the response function is not invertible, by studying a weaker rank-1 convexity notion, monotonicity, applied to a general class of nonlinear strain-limiting models. It is shown that the generalized monotonicity holds for Green-St.Venant strains with sufficiently small norms, and fails (through demonstration by counterexample) when the small strain constraint is relaxed. (Received July 29, 2014)

1106-74-491 **S M Mallikarjunaiah*** (mmallikarjuna@math.tamu.edu), Mail Stop 3368 Department of Mathematics, Texas A&M University, College Station, TX 77843, and **Jay R. Walton** (jwalton@math.tamu.edu), Mail Stop 3368 Department of Mathematics, Texas A&M University, College Station, TX 77843. *Numerical Modeling of Plane-Strain Fracture in the Context of a Strain-Limiting Theory of Elasticity.* Preliminary report.

The classical theory of Linearized Elastic Fracture Mechanics (LEFM) suffers two logical inconsistencies in that it predicts an elliptical crack-opening profile and an unbounded crack-tip strain while the theory was predicated upon the assumption of infinitesimal strain. Implicit strain-limiting theories of elasticity offers a novel approach for modeling fracture by limiting strains to a physically realistic level. A subclass of implicit models allows the linearized elastic strain to be a non-linear function of the Cauchy stress. In this work we study the problem of plane-strain fracture in the context of a strain-limiting theory of elasticity. The inverted constitutive relation along with the equilibrium equations give rise to a second order quasi-linear partial differential equation with displacement as the unknown. The mathematical model incorporates the classical fracture boundary conditions. By using a damped Newton's, method we construct a linearized version of the strong form from which the numerical solution was obtained using Adaptive Finite Element Method (AFEM). The results of this numerical study indicate that even very near the (mathematical) crack tip, both stress and strain remain much smaller in magnitude than the corresponding predictions from LEFM. (Received September 08, 2014)

1106-74-712 **Kun Gou*** (kgou@msu.edu), Michigan State University, Department of Mechanical Engineering, East Lansing, MI 48824, and **Thomas J Pence**, Michigan State University, Department of Mechanical Engineering, East Lansing, MI 48824. *Analysis of several compressible versions of the incompressible neo-Hookean material.*

We consider three different compressible versions of the conventional incompressible neo-Hookean material model. The different versions are not new and have been used in various model studies. They each give neo-Hookean behavior in an appropriate incompressible limit. The three versions each show some basic differences with respect to each other as regards the qualitative nature of the approach to the neo-Hookean limit. The purpose of this study is to exhibit these differences. (Received September 05, 2014)

1106-74-853 **Matthias Augustin*** (augustin@mathematik.uni-kl.de), University of Kaiserslautern, Department of Mathematics, P. O. Box 30 49, 67653 Kaiserslautern, Germany. *Methods of Fundamental Solutions in Poroelasticity.*

Geothermal energy, one of the most promising renewables, has a high need for stress field modeling due to the necessity to increase productivity of geothermal reservoirs by hydraulic fracturing but also to prevent uncontrolled stress releases, i.e., earthquakes.

This talk introduces a new numerical method to model the stress field in a geothermal reservoir including poroelastic effects. This method, based on the method of fundamental solutions, is a mesh-free, integration-free boundary method. We present theoretical results on the density of suitable fundamental solutions systems, which are the basis for two different ansatzes, as well as numerical results in two dimensions to evaluate the performance of the method and compare our two ansatzes. The talk is completed by a short discussion of an example on a three-dimensional domain. (Received September 08, 2014)

76 ► Fluid mechanics

1106-76-126 **Jonathan D Gutierrez** and **Megan Michelle Sorenson*** (megan.sorenson@eagles.cui.edu). *Modeling Fluid Flow Induced by* C. elegans *Swimming at Low Reynolds Number.*

C. elegans have been extensively researched regarding locomotion. However, most mathematical studies have focused on body dynamics rather than the fluid. As the nematodes undulate in a sinusoidal fashion, they cause fluid movement that has been studied experimentally but not modeled computationally on this scale. Utilizing the Navier-Stokes equation, regularized stokeslets, and the method of images, we computed the dynamics of the surrounding fluid. Our results strikingly matched experimental outcomes in various ways, including the distance particles travelled in one period of undulation, as well as qualitatively and quantitatively matching velocity fields. We then implemented this method using video data of swimming *C. elegans* and successfully reproduced the fluid dynamics. This is a novel application of the method of regularized stokeslets that combines theory and experiment. We expect this approach to provide insight in generating hypotheses and informing experimental design. (Received July 25, 2014)

1106-76-746 **Silvia Jimenez Bolanos*** (sjimenez@colgate.edu) and **Bogdan Vernescu**. *Navier Slip Condition for Viscous Fluids on a Rough Boundary.*

We study the effect of surface roughness on fluid flow over a solid surface. We are able to derive asymptotically an effective slip boundary condition (Navier slip condition) as a corrector to the no-slip condition on the surface. (Received September 05, 2014)

1106-76-791 **Tucker Hartland*** (tucker.hartland@gmail.com), **Ravi Shankar** and **Sergei A Fomin**. *Using the inviscid Burgers equation and the nonlinear shallow water equations to compute the time of wave breaking.*

The inviscid Burgers equation and the nonlinear shallow water equations are solved numerically in application to water wave breaking. As an alternative to complicated numerical methods based on the locating the first intersection of the characteristic lines, a simple finite difference scheme is used to compute the time when the wave energy first starts to dissipate. A flux limiter is used to minimize spurious diffusion. To compensate for numerical error introduced by integrating near the steep wave front, a local averaging method is used to smooth the energy curve. The numerical results give good agreement with analytical breaking times. (Received September 14, 2014)

1106-76-824 **Xiaoming Wang*** (wxm@math.fsu.edu). *Flow is karstic geometry.*

Karst type geometry is a particular type of configuration that consists of both conduit/channel (or vug/chamber) together with porous media. Many important applications involve fluid flows in karstic geometry. Well-known examples include contaminant transport in karst aquifer, oil recovery in karst oil reservoir, proton exchange membrane fuel cell technology, cardiovascular modeling, and carbon-dioxide sequestration among others. The mathematical study of flows in karst geometry is a challenge due to the coupling of the flows in the conduits and flows in the surrounding matrix which are governed by different physical processes, the possibly complex geometry of the network of conduits, the vastly disparate spatial and temporal scales, the strong heterogeneity and the enormous associated uncertainty with natural karst aquifer, and the multi-phase nature of many important applications. In this talk, we will present recent results on the modeling, analysis and simulation of single phase as well as two-phase flows in karstic geometry. (Received September 07, 2014)

1106-76-939 **Eleftherios Gkioulekas***, University of Texas-Pan American, Department of Mathematics, 1201 West University Drive, Edinburg, TX 78539-2999. *Revisiting the dissipation scales of the energy cascade of 3D turbulence as anomalous scaling functions.* Preliminary report.

The usual concept of an energy cascade that has a unique associated dissipation scale is an oversimplification. Aside from the fact that self-similar scaling for higher-order structure functions terminates at different dissipation scales, back in 1996, L'vov and Procaccia noted an additional anomaly; starting from an n^{th}-order generalized structure function, consisting of a product of velocity differences, each between two different points, when all velocity difference separations have length scale R and one velocity difference separation is reduced to a smaller scale r, the crossover to dissipation range will occur at the scale $\ell_n(R)$ which is R-dependent. The fixed point λ_n such that $\ell_n(\lambda_n) = \lambda_n$ gives the standard dissipation scale associated with the n^{th}-order standard structure functions. In my talk, I will make note of an additional anomaly. If, instead of reducing one velocity difference separation, we reduce p velocity difference separations to scale r , that defines a different dissipation scale function $\ell_{np}(R)$ and a different fixed-point λ_{np}. The new anomaly is that λ_{np} is not independent of p, as a result of intermittency corrections. (Received September 08, 2014)

1106-76-1037 **Goong Chen** (gchen@math.tamu.edu) and **Cong Gu*** (gucong@math.tamu.edu). *Malaysia Airlines Flight MH370: A Numerical Modeling and Simulation Study of Airplane Crash and Water Landing.*

On March 8, 2014, Malaysia Airlines flight MH370 disappeared less than an hour after take-off on a route from Kuala Lumpur to Beijing. Its mysterious fate is one of the most intriguing stories of the year 2014, but the available evidence has indicated that the airliner has crashed into the Indian Ocean. Its search and recovery operation also has constituted the most expensive one in the aviation history so far.

In this talk, the speaker will first revisit the study of crashing and ditching of aircraft into the ocean as a classical water-entry problem in applied mathematics. Then the entry of an airliner into the ocean will be modeled as a two-phase fluid-structure interation problem with compressible aero-hydrodynamics and six-degree of freedom of motion. Numerical simulations are performed by using the OpenFOAM software with dynamic mesh. Some splitting algorithms, PISO, will be described. Several video simulations of dynamic motion of an airliner flying into the ocean will be shown. Impact damage will also be assessed based on the analysis of the Space Shuttle Challenger disaster.

This is joint work by G. Chen, C. Gu, P.J. Morris, E.G. Paterson, A. Sergeev, Y.-C. Wang and T. Wierzbicki. (Received September 09, 2014)

1106-76-1426 **Daozhi Han*** (dhan@math.fsu.edu), 1327 High RD, Apt. H1, Tallahassee, FL 32304, and **Xiaoming Wang**, **Dong Sun** and **Hao Wu**. *A diffuse interface model for two phase flow in karst aquifers.*

Multiphase flow phenomena are ubiquitous in nature. Multiphase flows also play an important role in many engineering and environmental science applications. In some applications such as flows in karst aquifers, karst oil reservoir, proton membrane exchange fuel cell, multiphase flows in conduits and in porous media must be considered together. How free flows in conduit/channel interact with flow in porous media is a challenge.

In this talk we present a phase field model that couples two phase flow in conduit with two phase flow in porous media. The model together with the associated interface boundary conditions are derived utilizing Onsager's extremum principle, which enjoys a physically important energy law. We show the existence of global in time finite energy solution to the model in both 2D and 3D. Uniqueness of weak-strong solution can be established as well. Finally some numerical results will be provided using the proposed phase field model. (Received September 12, 2014)

1106-76-1651 **Sergei A Fomin*** (sfomin@csuchico.edu), Department of Mathematics and Statistics, California State University, Chico, Chico, CA 95929, and **Ravi Shankar** and **Vladimir A Chugunov**. *Wave propagation over the shelf or isolated obstacle.*

A solitary wave propagation over an underwater rectangular depth discontinuity is examined using perturbative analysis. The linear wave solutions are used to generate higher order nonlinear corrections; these corrections are rendered uniformly valid using the method of renormalization. In particular, the physical principles of energy and momentum balance are each used to generate different conjugation conditions at the stepped depth discontinuity. The results of implementing the boundary conditions in the perturbative analysis are presented and compared. The effects of the geometry of underwater barriers on the wave propagation are demonstrated (Received September 14, 2014)

1106-76-1652 **Aseel Farhat*** (afarhat@indiana.edu), **Evelyn Lunasin** and **Edriss Titi**. *A New Data Assimilation Algorithm for the 2D Navier-Stokes equations and the 3D α-Models of Turbulence.*

We introduce an abridged continuous data assimilation algorithm for the 2D Navier-Stokes, 2D Bénard problem and 3D subgrid scale α-models of turbulence. The novelty of this improved algorithm is on the reduction on the components of the observational data that needs to be measured and inserted into the model equation, in the form of a feedback control term, to recover the unknown reference solution. We show that for the 2D Navier-Stokes equations the approximate solutions constructed using observations in only one component of the velocity field converge in time to the reference solution. In the case of the 3D Leray-α model, we show that the approximate solutions constructed using only observations any two components, without any measurements on the third component, of the velocity field converge in time to the reference solution. (Received September 14, 2014)

1106-76-1942 **Ray Treinen***, Department of Mathematics, Texas State University, 601 University Drive, San Marcos, TX 78666. *On floating equilibria in a finite container.*

We consider the two dimensional problem of a circular object floating in a finite container under capillary effects. We organize and classify the possible equilibria according to variational conditions and give numerical support for a conjecture on existence and uniqueness. (Received September 15, 2014)

1106-76-2742 **Omid Khanmohamadi*** (okhanmoh@math.fsu.edu). *Simultaneous Space–Time Adaptive Wavelet Collocation for Modelling the Meditranian Eddies ("Meddies").* Preliminary report.

Developing physically-consistent and computationally-feasible ocean models is an integral component of modelling our local ecosystems and the global climate. This work concentrates on modelling "meddies", the salty, warm-water eddies which originate in the Meditranian Sea and sink in the Atlantic Ocean. Being isolated and rapidly-rotating bodies of water in the ocean, these meddies present a challenging tracking problem for whose solution an adaptive wavelet "collocation" method is introduced to vary *simultaneously in space and time* the underlying discretization of the continuum Navier–Stokes model, a posteriori, providing higher effective resolution and lower computational cost, as well as global control on the time integration error. Novel boundary conditions are introduced to model the transfer of salinity through the Strait of Gibraltar. Volume penalization methods are introduced to improve the representation of the bottom bathymetry and continental topology. (Received September 16, 2014)

78 ► Optics, electromagnetic theory

1106-78-578 **Duc D Nguyen*** (`ddnguyen2@crimson.ua.edu`), Tuscaloosa, AL 35401, and **Shan Zhao**, University of Alabama. *High order FDTD methods for electromagnetic systems in dispersive inhomogeneous media.*

Dispersive media are often encountered in the nature such as in rock, soils, plasma and biological tissues. The study of dispersive materials is, therefore, crucial to a wide range of electromagnetic applications. For instance, the ground penetrating radar (GPR) and microwave imaging for early detection of breast cancer are involved in dealing with dispersive soil and dispersive tissue respectively. In such media, the permittivity is known to be a function of frequency so that a broadband electromagnetic wave will propagate in a frequency dependent manner. The auxiliary differential equations (ADE) are employed to track the transient changes of field regularities across the dispersive interfaces. Novel finite-difference time-domain (FDTD) algorithms based on the matched interface and boundary (MIB) method are constructed to rigorously enforce the time-dependent jump conditions. High order convergences are numerically achieved in solving dispersive interfaces with complex shapes. (Received September 02, 2014)

1106-78-1005 **Kaitlyn Voccola*** (`voccola@math.colostate.edu`). *Synthetic Aperture Correlation Imaging.*

In synthetic-aperture radar (SAR) imaging, a scene of interest is illuminated by electromagnetic waves. The goal is to reconstruct an image of the scene from the measurement of the scattered waves using airborne antenna(s). A new imaging algorithm, known as correlation imaging, is suggested in which an image is formed of the reflectivity function squared. The algorithm uses what is often called the correlation function in place of the standard slow and fast time data. The correlation function is found via a simple preprocessing step applied to the collected data. A backprojection algorithm is formulated using microlocal analysis. We analyze the ability of the correlation imaging technique to mitigate clutter effects on the image. In addition we consider the case of polarimetric correlation SAR. (Received September 09, 2014)

1106-78-2411 **Robert P Viator Jr*** (`rviato2@lsu.edu`) and **Robert Lipton**. *Asymptotic Analysis of High-Contrast Photonic Crystals.* Preliminary report.

We consider quasi-periodic transverse-electric modes traveling through a photonic crystal. The crystal is a periodic array of unit cells Y consisting of two phases (the *inclusion* $D \Subset Y$ and the *host* $Y \setminus D$) made of isotropic materials, where the electric permittivity $\varepsilon_D = d$ in D is much higher than the permittivity in the host $Y \setminus D$. We calculate a power series expansion for the frequency ω^2 in terms of d and show a lower bound for its radius of convergence using spectral techniques arising from layer potentials and perturbation analysis. (Received September 16, 2014)

80 ► Classical thermodynamics, heat transfer

1106-80-1150 **Sarah Maria Eberle*** (`eberles@rhrk.uni-kl.de`), Geomathematics Group, University of Kaiserslautern, P.O. Box 3049, Kaiserslautern, 67653, **Willi Freeden** (`freeden@mathematik.uni-kl.de`), Geomathematics Group, University of Kaiserslautern, P.O. Box 3049, Kaiserslautern, 67653, and **Ulrich Matthes** (`ulrich.matthes@klimawandel-rlp.de`), Competence Centre for Climate Change Impacts, Hauptstraße 16, Trippstadt, 67705. *Modeling of Forest Fire Spreading with Radial Basis Functions.*

Due to the climate change, the forest fire risk is increasing. This is the reason why, we have to take a closer look at the interacting ingredients which influence forest fires. In particular, we have to deal with the modeling of the chemical and physical processes as combustion as well as heat and mass transfer mechanisms to describe forest fire spreading. Altogether, modeling leads to a convection-diffusion-reaction-problem describing the temperature and the mass fraction of the fuel.

In order to solve the problem numerically, we choose radial basis functions as ansatz functions for a collocation method for space discretization and apply a time step scheme. We introduce a particular stabilization technique using flux corrected transport tools, which is helpful in the numerical treatment of the underlying equations and more concretely, for the convection-dominated case. Finally, we present some simulations of forest fire spreading for different parameter configurations based on data provided by the Rhineland-Palatinate Centre of Excellence for Climate Change Impacts. (Received September 11, 2014)

81 ► Quantum theory

1106-81-87 **Harry A. Watson*** (harry.watson@att.net), 12857 Pattison St., Eastvale, CA 92880. *An Approximation to the Mass Ratio of the Proton to the Electron.* Preliminary report.

The mass ratio of the proton to the electron is a dimensionless physical constant. The following expression provides a good estimate:

$$(4\pi)\left(4\pi - \frac{1}{\pi}\right)\left(4\pi - \frac{2}{\pi}\right) = 1836.15 \tag{1}$$

The above equation is also the greatest lower bound (GLB) for a more general expression. A geometric persuasion is given and the more general expression is determined via the inversion of the spheres. (Received July 07, 2014)

1106-81-157 **Pavel Etingof** and **Chelsea Walton*** (notlaw@math.mit.edu). *Semisimple Hopf actions on quantizations.* Preliminary report.

We study actions of semisimple Hopf algebras H on filtered deformations B of commutative domains such as algebras of differential operators on a smooth affine irreducible variety, universal enveloping algebras of a finite dimensional Lie algebra, symplectic reflection algebras, and quantized quiver varieties. We show that the action of H on B must factor through a group algebra, or in other words, if H acts inner faithfully on B, then H is cocommutative. The techniques used include reduction modulo p and the study of semisimple cosemisimple Hopf actions on division algebras. (Received August 01, 2014)

1106-81-290 **Rachael C. Alvir*** (arubirurei@gmail.com), 170 Red Sand Road, Grand Junction, CO 81507, and **Sophia Dever**. *Quantum Walks on Graphs.*

A continuous-time quantum walk on a graph $G = (V, E)$ is given by the unitary matrix $U_G(t) = e^{-itA(G)}$, where $A(G)$ is the adjacency matrix of G. We say that G exhibits *perfect state transfer* between vertices $a, b \in V$ at time t if $|U(t)_{a,b}| = 1$. These notions have been studied in the context of developing efficient quantum algorithms and also in simulating universal quantum computation. We study the effect on the walk when the laplacian, signless laplacian, or normalized laplacian is used in place of the adjacency matrix. Our results found connections between the various types of walks when examining perfect state transfer on graph products and a connection with the line graph, yielding new infinite families of graphs which exhibit perfect state transfer. (Received August 19, 2014)

1106-81-406 **Carlos F. Lardizabal*** (cfelipe@mat.ufrgs.br), Instituto de Matemática - UFRGS, Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves 9500, Porto Alegre, RS 91509-900, Brazil. *Open quantum random walks and the recurrence problem.* Preliminary report.

In this seminar we discuss a model of open quantum random walk on $\mathbb{Z}$, and there we examine a notion of quantum recurrence. Combining some classical and quantum ideas, one can also analyze positive recurrence. The calculation of probabilities is typically noncommutative (via trace functionals), but globally the walk presents certain classical properties. We briefly discuss nonhomogeneous Markov chains associated to this kind of walk. Part of this presentation is related to joint work with Rafael Rigão Souza (UFRGS). (Received August 27, 2014)

1106-81-756 **Edward G. Effros*** (ege@math.ucla.edu), Mathemaics Department, UCLA, Los Angeles, CA 90095-1555. *Quantum Variables.*

Although the mathematical notions of quantized variables were first considered in the late twenties by von Neumann, it wasn't until the forties that such researchers as Segal, Kadison, Singer, and Dixmier realized their importance in mathematics. Finite density matrices provide the simplest examples. In this model, one replaces probability measures $p = (p_1, \ldots, p_n)$, where $(p_j \geq 0, \sum p_j = 1)$ by density matrices $\rho = [\rho_{ij}]$ which are positive semidefinite, and for which $\mathrm{tr}(\rho) = \sum \rho_{ii} = 1$. The parallel between these quantities is best understood if one regards them as states on the C^*-algebras $\mathbb{C}^n$ and $\mathbb{M}_n$, respectively. From the point of view of thermodynamics, the entropies $H(p) = \sum p_j \log p_j$ and $S(\rho) = \mathrm{tr}(\rho \log \rho)$ provide important invariants. Subsequently, it was discovered that the seemingly unnatural relative entropies $H(p||q) = \sum p_j \log p_j - p_j \log q_j$ and $S(\rho||\sigma) = \mathrm{tr}(\rho \log \rho -$

$\rho\log\sigma$) are even more fundamental. The remarkable parallels between these quantities and their applications to such areas as classical and quantum information theory will be reviewed. (Received September 05, 2014)

1106-81-799 **Xingshan Cui*** (xingshan@math.ucsb.edu) and **Zhenghan Wang**. *Universal Quantum Computation with Metaplectic Anyons.*

We show that braidings of the metaplectic anyons X_ϵ in $SO(3)_2 = SU(2)_4$ with their total charge equal to the metaplectic mode Y supplemented with measurements of the total charge of two metaplectic anyons are universal for quantum computation. We conjecture that similar universal anyonic computing models can be constructed for all metaplectic anyon systems $SO(p)_2$ for any odd prime $p \geq 5$. In order to prove universality, we find new conceptually appealing universal gate sets for qutrits and qupits. (Received September 06, 2014)

1106-81-1245 **Pieter Naaijkens*** (pieter.naaijkens@itp.uni-hannover.de), Institute for Theoretical Physics, Leibniz University Hannover, 30167 Hannover, Germany. *Operator algebras and topological quantum phases.*

One of the striking features of topologically ordered phases of matter is that they have quasi-particle excitations with peculiar properties: they do not behave like bosons or fermions, but rather as anyons. That is, if one exchanges two of such quasi-particles, one can get something more interesting operation on the state of the system than just a sign change. Mathematically such anyons can be realized as equivalence classes of representations of a C^*-algebra of observables. In this talk I will explain how one can use operator algebraic methods to further study these anyons. In particular, I will explain how we can look at the inclusion of certain (von Neumann) algebras of observables to learn something about the quantum dimension of the system. (Received September 11, 2014)

1106-81-1325 **F . Alberto Grünbaum*** (grunbaum@math.berkeley.edu), Berkeley, CA 94720. *Return properties for Quantum walks.*

I will discuss the use of Schur function technology to discover an understand some rather surprising properties of quantum walks that have some topological/geometric interpretation. This is part of joint and continuing work with Luis Velazquez, Reinhard Werner, Albert Werner, Jean Bourgain and Jon Wilkening. (Received September 12, 2014)

1106-81-1331 **Norio Konno** (konno@ynu.ac.jp), Hodogaya, Yokohama, Kanagawa 240-8501, Japan, **Yusuke Higuchi** (higuchi@cas.showa-u.ac.jp), Fujiyoshida, Yamanashi 403-0005, Japan, **Iwao Sato*** (isato@oyama-ct.ac.jp), Oyama, Tochigi 323-0806, Japan, and **Etsuo Segawa** (e-segawa@m.tohoku.ac.jp), Sendai, Miyagi 980-8579, Japan. *A note on the discrete-time evolutions of quantum walk on a graph.*

Recently many researchers in various fields pay attention to the quantum walk on graphs. The Grover evolution matrix of a graph is efficient for the graph isomorphism problem, and various approach are done in the graph isomorphism problem. The spectrum of the Grover evolution matrix of a graph G is given from that of the transition operator of a simple random walk on G. Furthermore, the Szegedy evolution matrix of a quantum walk on a graph G is given from that of the transition operator of a random walk on G.

One of our main purposes is to generalize the above facts on the Grover evolution matrix and the Szegedy evolution matrix. We present a generalized evolution matrix of a graph and compute its characteristic polynomial. (Received September 12, 2014)

1106-81-1359 **F. Alberto Grünbaum** and **Takuya Machida*** (machida@stat.t.u-tokyo.ac.jp). *Limit distribution of a 3-period time-dependent quantum walk.*

Quantum walks are quantum analogs of random walks and their long-time limit theorems have been computed since 2002. In my talk, we take care of a discrete-time quantum walk on the line. The quantum walker is operated by time-dependent operators. We present a long-time limit distribution for a 3-period time-dependent quantum walk. The limit distribution shows an interesting behavior which one never has in a time-independent quantum walk or a 2-period time-dependent quantum walk [1,2]. The result in my presentation is based on [3].

[1] N. Konno : Quantum random walks in one dimension, Quantum Information Processing, 1(5), pp. 345–354 (2002).
[2] T. Machida and N. Konno : Limit theorem for a time-dependent coined quantum walk on the line, F. Peper et al. (Eds.): IWNC 2009, Proceedings in Information and Communications Technology, 2, pp. 226–235 (2010).
[3] F. A. Grunbaum and T. Machida : A limit theorem for a 3-period time-dependent quantum walk, Quantum Information and Computation, Vol.15 No.1&2, pp. 50–60 (2015). (Received September 14, 2014)

1106-81-1492 **Mingsheng Ying*** (mingsheng.ying@uts.edu.au), Centre for Quantum Computation and, Intelligent Systems, University of Technology, Sydney, Sydney, NSW 2121, Australia. *Quantum Recursion and Second Quantisation.*

This paper introduces a new notion of quantum recursion of which the control flow of the computation is quantum rather than classical as in the notions of recursion considered in the previous studies of quantum programming. A typical example is recursive quantum walks, which are obtained by slightly modifying the construction of the ordinary quantum walks. The operational and denotational semantics of quantum recursions are defined by employing the second quantisation method, and they are proved to be equivalent. (For full paper, see: http://arxiv.org/pdf/1405.4443v2.pdf) (Received September 13, 2014)

1106-81-1747 **Marcel Bischoff*** (marcel.bischoff@vanderbilt.edu), Vanderbilt University, Department of Mathematics, Nashville, TN 37203, and **Yasuyuki Kawahigashi**, **Roberto Longo** and **Karl-Henning Rehren**. *Subfactors and Topological Defects in Conformal Quantum Field Theory.*

Models in relativistic quantum field theory can be described by so-called local nets of von Neumann algebras. Rich structures arise by the study of conformal QFT on two-dimensional space time. We introduce the notion of topological defects between such theories. Given a completely rational conformal net $\mathcal{A}$ on the circle, we give a classification of all full conformal QFT models based on $\mathcal{A}$ and its topological defects in terms of the data in the representation category of $\mathcal{A}$. The result is obtained and can naturally be formulated in terms of braided subfactors and tensor categories. (Received September 15, 2014)

1106-81-1986 **Chaobin Liu*** (cliu@bowiestate.edu), Department of Mathematics, Bowie State University, 14000 Jericho Park Road, Bowie, MD 20715, and **Nelson Petulante** and **Forrest Ingram-Johnson**. *On the behavior of quantum walks confined to a cycle coupled with a half line.* Preliminary report.

When confined to a topological medium consisting of a cycle coupled with a half-line, quantum walks tend to exhibit long-term statistical tendencies which differ dramatically from the tendencies of classical random walks on the cycle-plus-half line setting. In particular, as suggested by numerical simulations, the position probability distribution of the walker tends to dichotomize, in part, into a non-stationary distribution on the cycle and, in part, into a ballistic distribution on the half line. By contrast, the position probability distribution of the classical random walker present nice uniform distributions on the cycle at large times, and tends always to vanish on the cycle and to migrate completely to the half-line as a purely diffusive process. (Received September 15, 2014)

1106-81-2149 **Eric Berry*** (edberry@email.wm.edu), **Dean Katsaros**, **Chi-Kwong Li** and **Diane Pelejo**. *Positive Semidefinite Matrices with Special Block Structure.*

Let M_n be the set of $n \times n$ complex matrices. In quantum information science, quantum states are represented as density matrices, i.e., positive semidefinite matrices with trace 1, and quantum operations on quantum states can be identified with positive semidefinite matrices with special structure. In this talk, we will present some recent findings on the eigenvalues of density matrices with maximally mixed reduced states. The collection of such density matrices can be described as

$$S\left(\frac{I_n}{n}\right) = \left\{\rho = (\rho_{ij})_{1 \le i,j \le 2} \in M_{2n} : \rho_{11} + \rho_{22} = \frac{I_n}{n}\right\}.$$

Up to a multiple, the matrices in this set corresponds to quantum operations from M_n to M_2. Thus, our results also have implications on quantum operations. (Received September 16, 2014)

1106-81-2153 **Jingcheng Dong*** (dongjc@njau.edu.cn), College of Engineering, Nanjing Agricultural University, Nanjing, Jiangsu 210031, Peoples Rep of China, and **Henry Tucker** (htucker@usc.edu), Department of Mathematics, University of Southern California, Los Angeles, CA 90089. *On integral modular categories of Frobenius-Perron dimension pq^n.*

Let p, q be distinct prime numbers. We prove that integral modular categories of Frobenius-Perron dimension pq^5 are group-theoretical. Combining this with previous results in the literature, integral modular categories of Frobenius-Perron dimension pq^i, $0 \le i \le 5$, are group-theoretical. We also prove a sufficient and necessary condition for integral modular categories of Frobenius-Perron dimension pq^n being group-theoretical, under the restriction that $p < q$, where n is a positive integer. (Received September 15, 2014)

1106-81-2176 **Yusuke Ide***, 3-27-1 Rokkakubashi, Kanagawa-ku, Yokohama, Kangawa 221-8686, Japan. *Rényi entropy for discrete-time quantum walks on the line.*

Rényi entropy is an important quantity in the information theory because it includes several useful entropy measures such as Shannon entropy, Min-entropy and so on, as special choices of its parameter. In this talk, we show a limiting behavior of the Rényi entropy for discrete-time quantum walks on the line which are starting from the origin and defined by arbitrary coin and initial state. The result shows that the Rényi entropy tends to infinity in logarithmic order of time and difference between the Rényi entropy and the logarithmic function characterizes by the Rényi entropy of the limit distribution of the quantum walk. (Received September 16, 2014)

1106-81-2181 **Mina Aganagic***, mina@math.berkeley.edu. *String Theory and Math: Why This Marriage May Last.* Preliminary report.

The relationship of mathematics and physics has a very long history. From time to time, the fields developed together, only to drift apart. With string theory, the nature of the relationship has changed, perhaps forever. In this talk, I will try to explain why, and illustrate it through examples. (Received September 16, 2014)

1106-81-2230 **Chandrashekar Channipura Madaiah*** (c.madaiah@oist.jp), Quantum systems Unit, Okinawa Institute of Science and Technologu, 1919-1 Tancha, Onna-son, Okinawa 9040495, Japan. *Disorder and noise as passage for interplay between localization and diffusion of quantum walk.*

It has been shown by many earlier works that the disorder induces a dramatic change in the interference pattern leading to localization of the quantum walks in one- and two-dimensions. In this talk we will present the time evolution of one- and two-dimensional discrete-time quantum walk with different degree of disorder and study its effect on the quantum correlation (negativity). We use spatial, temporal and spatio-temporal broken periodicity of the unitary evolution as disorder and analytically show the dynamics leading to localization. We focus on the transition point in the degree of disorder leading to the localization of the walk which normally spreads linearly with steps. We also show the decrease in the particle and position quantum correlation with spatial disorder and counter intuitively, an enhancement in correlations with temporal and spatio-temporal disorder will also be presented.

By introducing a small amount of noise into the disordered dynamics we show the passage from the localized to the diffusive dynamics. This brings up a variety of intriguing questions relating to the role of disorder and noise in the interplay between localization (Anderson Localization) and diffusion of quantum dynamics. (Received September 16, 2014)

1106-81-2768 **Yuting Hu*** (yuting@physics.utah.edu), **Brendan G. Pankovich** (ren.pankovich@utah.edu) and **Yong-Shi Wu** (wu@physics.utah.edu). *Entanglement Spectra in Levin-Wen models for Topological Phases in Two Dimensions.*

We obtain explicitly the entanglement spectrum of ground states and excited states of the doubled Fibonacci Levin-Wen model. We show that the entanglement spectrum has the topological degeneracy, which coincides with that of a 1d chiral Fibonacci anyon system. Then we establish a correspondence between the entanglement entropy of the bulk bipartition and the entropy of a grand canonical ensemble of 1d chiral Fibonacci anyon system on the boundary, at a finite temperature determined by the quantum dimension of Fibonacci anyons. Finally, we discuss how the topological quantum numbers of a bulk subsystem can be detected by the entanglement spectrum. (Received September 16, 2014)

1106-81-2927 **Francesco Petruccione*** (petruccione@ukzn.ac.za), School ofChemistry and Physics, Westville CAmpus, University of KwaZulu-Natal, Durban, KZN 4001, South Korea. *Open Quantum Walks.*

Recently, a formalism for discrete time open quantum walks was introduced [S. Attal et al., J. Stat. Phys., 147 (2012) 832; S. Attal, F. Petruccione, I. Sinayskiy, Phys. Lett. A, 376 (2012) 1545]. This formalism is exclusively based on the non-unitary dynamics induced by the environment. This approach rests upon the implementation of appropriate completely positive maps. Open quantum walks include the classical random walk and through a realization procedure a connection to the Hadamard quantum walk is established. Open quantum walks allow for an unravelling in terms of quantum trajectories. It was shown [I. Sinayskiy and F. Petruccione, QIP 11 (2012) 1301] that open quantum walks can perform universal quantum computation and can be used for quantum state engineering. Microscopic derivation of open quantum walks in a system-environment approach will be presented and discussed in various limits. (Received September 17, 2014)

82 ► Statistical mechanics, structure of matter

1106-82-2710 **Joel D Nishimura*** (joel.nishimura@asu.edu), PO Box 37100, Phoenix, AZ 85069-7100, and **Timothy P Novikoff** (tnovikoff@gmail.com), New York, NY. *The Familiarity Curve of the Slow Flashcard System.* Preliminary report.

In the algorithmic theory of education there is a natural trade-off between reviewing/reinforcing old material and exposure to new material. This trade-off is captured in the recently introduced discrete, deterministic 'Slow Flashcard Schedule' (SFS) system; a mathematically simple system capable of remarkable complexity reminiscent of a quasi-random number generator. We further the recent work on the SFS by modeling the discrete and deterministic SFS with a probabilistic system that shares key properties with the SFS. From this probabilistic model we develop a continuous PDE model, which sheds light on the longterm behavior of the SFS. In addition to explaining the conjectured existence of the so called 'familiarity' curve, the derivation of a fully continuous model of learning allows for new avenues of research into a fundamental trade-off in learning. (Received September 16, 2014)

83 ► Relativity and gravitational theory

1106-83-489 **David Betounes***, Dept of Math & CS, Univ. of Texas, Permian Basin, 4901 E. University Blvd., Odessa, TX 79761. *The Geometry of Space-Time-Matter.*

We formulate a global, differential geometric structure for the space-time-matter theory introduced by Wesson and coworkers. In addition to giving a coordinate-free, intrinsic approach to the theory, we extend the discussion from 5-dimensions to arbitrary dimensions.

Our model for space-time-matter is a Ricci flat, semi-Riemannian manifold $(E, \overline{g})$, where E is a fiber bundle over M (the spacetime) and $\overline{g}$ is a Kaluza-Klein metric on E. Each space-time-matter manifold $(E, \overline{g})$ generates spacetimes $(M, \widetilde{g})$, one for each embedding of M in E, with stress-energy tensor for M determined by the geometry of E and the nature of the embedding. (Received August 30, 2014)

85 ► Astronomy and astrophysics

1106-85-1723 **Hriday Bharat Thakkar*** (thakkar.hriday@yahoo.com), Department of Mathematics and CS, Minot State University, Minot, ND , and **Narayan Thapa** (narayan.thapa@minotstateu.edu), Department of Mathematics and CS, Minot State University, Minot, ND. *A Study of Artificial Neural Network Techniques Used to Mine Data in Astronomy.* Preliminary report.

Artificial Neural Networks have a long history of being used as computational tools in various fields of sciences because of their machine learning and pattern recognition capability. In the recent decade, there has been a large scale increase in the collection of data of cosmic entities such as galaxies and stars, and of high energy physics. In addition to this, the difficulty associated with mining the large amounts of data led the astronomical community to begin implementing Artificial Neural Networks to perform various tasks ranging from classification of gamma-ray bursts to classification of galaxies to identifying a star from a galaxy and the like. In this talk, we discuss the various ANN techniques used in data mining. (Received September 15, 2014)

1106-85-2896 **Andras Balogh** (abalogh@utpa.edu), Department of Mathematics, The University of Texas-Pan American, 1201 W. University Drive, Edinburg, TX 78539, **Jacob N Banda*** (jnbanda@broncs.utpa.edu), Department of Mathematics, The University of Texas-Pan American, 1201 W. University Drive, Edinburg, TX 78539, and **Karen Yagdjian** (yagdjian@utpa.edu), Department of Mathematics, The University of Texas-Pan American, 1201 W. University Drive, Edinburg, TX 78539. *Numerical investigation of the equation for the Higgs boson in the de Sitter spacetime.*

In this talk we use various explicit numerical schemes on Graphical Processing Units (GPUs) to approximate solution of the equation for the Higgs boson in the de Sitter spacetime. Through these computer simulations we investigate the zeros of global solutions in the interior of their compact support. These so-called bubbles, their creation, growth and interactions are of great interest to particle physics and inflationary cosmology. Sufficient condition for their existence was shown by K. Yagdjian in 2012. (Received September 17, 2014)

86 ► Geophysics

1106-86-592 **Kanadpriya Basu*** (kbasu@utep.edu), 500 West University Avenue, El Paso, TX 79968, and **Maria Christina Mariani** (mcmariani@utep.edu), 500 West University Avenue, El Paso, TX 79968. *Interpolating techniques and non-parametric regression methods applied to geophysical and financial data analysis.* Preliminary report.

Two deterministic models are applied to a spatial earthquake data set that list all the earthquake magnitude in different locations in a certain time period. We further use the modified version of the same technique to analyze financial data in order to find a curve of best fit. Our modeling techniques turn out to be robust and accurate to handle these kind of data set, and could be combined in the future with stochastic models. (Received September 03, 2014)

1106-86-749 **W Van Snyder*** (van.snyder@jpl.nasa.gov), Jet Propulsion Laboratory, 4800 Oak Grove Drive, Mail Stop 183-701, Pasadena, CA 91109-8099. *Complications in atmospheric remotes sensing.*

When one thinks of atmospheric remote sensing using passive measurements of microwave radiation, one usually thinks of inverting the radiative-transfer equation.

One normally attacks such problems by starting with an hypothetical atmosphere, perhaps from climatological averages, then integrating the radiative-transfer equation through the current estimate of the atmosphere, along with derivatives of it with respect to the quantities of interest at places of interest, and iterating using a Newton method.

Aside from the mathematical difficulty of solving an ill-posed problem, complications arise: scattering, locations of the retrieved quantities, refraction, modeling the instrument, and surface albedo if the ray reflects from the surface.

We address some methods to resolve these difficulties. (Received September 05, 2014)

1106-86-1628 **Christian Gerhards*** (gerhards.christian@gmail.com), Vienna, Austria. *Multiscale Methods in Geomagnetic Modeling.*

The Earth's magnetic field consists of various contributions that reveal a different spatial, spectral, and temporal behaviour. Therefore, multiscale methods can be a useful tool for its investigation. In this talk, we give a brief overview on the different contributions before we focus on the lithospheric field, which can be described by a harmonic potential in the exterior of the Earth. We describe in some detail how adequate multiscale kernels and approximation methods can be constructed that pay tribute to the available data situation (i.e., global data on a satellite orbit and regional data at the Earth's surface) as well as the spatial variability of the lithospheric magnetic field. (Received September 14, 2014)

1106-86-1827 **T. Malysheva*** (malysheva@ou.edu) and **L. White** (lwhite@ou.edu). *Well Posedness Theory for a Coupled Thermo-Chemo-Poroelastic System.* Preliminary report.

We will present the well posedness theory for a coupled thermo-chemo-poroelastic (TCPu) system. This study is motivated by the problems of borehole stability in fluid-saturated chemically active porous formations that involve the modeling of fully coupled thermal, chemical, hydraulic, and mechanical processes. The underlying TCPu model is a system of time-dependent parabolic partial differential equations (PDEs) coupled with Navier-type elliptic PDEs with time as a parameter. The parabolic equations represent heat, solute, and fluid diffusions, and the Navier-type elliptic equations attempt to capture the elastic behavior of rock while incorporating thermal, chemical, and porous media effects. The well posedness results are based on the Faedo-Galerkin approximation of the parabolic system and on the principle of the minimum total potential energy with Korn's inequalities applied to the elastic Navier-type system. (Received September 15, 2014)

1106-86-1997 **James D. Walker*** (james.walker@swri.org), 6220 Culebra Road, San Antonio, TX 78238, and **Sidney Chocron**, **Rory P. Bigger** and **Trent Kirchdoerfer**. *Asteroid seismology: using natural frequencies distribution to infer internal structure.*

Our solar system is full of small bodies in the form of asteroids and comet nuclei. Seismology is the only mechanism we currently have for looking at the interior of these objects to provide clues as to structure and origin. Seismology has been very successful in exploring the interior structure of the Earth, but for small bodies at remote locations in the solar system we are heavily constrained by the number of seismic sources and measuring devices, probably only 2 to 3 for each for a space mission. One approach to utilizing the limited instrumentation is to study the full body vibrations or spectrum. Asteroids and comet nuclei have varied outer shapes, as well as the possibility of interior structure ranging from rubble piles to large monolithic pieces. Eigenvalue distributions are affected by both exterior shape and interior structure. We display the natural frequency (eigenvalue) distribution for a sphere, an ellipsoid, and from computations assuming the outer surface shape of asteroid Itokawa, where a detailed surface map exists due to the Japanese Hayabusa mission. The distributions show qualitative behavior relating to both outer shape and interior structure. This work is in support of efforts to include a seismology experiment on a space mission to an asteroid. (Received September 15, 2014)

1106-86-2034 **Alain Plattner*** (aplattner@csufresno.edu) and **Frederik J Simons**. *High-resolution crustal magnetic-field model of the Martian South Pole using altitude vector Slepian functions.*

Within the last decade a variety of local planetary crustal magnetic field inversion methods has become available, including spherical wavelets, spherical cap harmonics, Slepian functions, and altitude Slepian functions. To date, however, examples of where local inversions have unveiled previously obscured features and hence contributed to our practical knowledge of planetary crustal fields are wanting. We apply our altitude vector Slepian inversion to obtain a local crustal field model for the Martian South Pole. This model reveals previously unseen features. The magnetic-field data collected by NASA's Mars Global Surveyor satellite mission are particularly suited for a local inversion. Their quality and altitude vary strongly and include a patch of low-altitude, low-noise data over the South Pole. Besides inverting for a crustal magnetic-field model of the Martian South Polar region, we investigate the effect of inverting for the crustal field of subregions therein. We observe that the inversion of regions containing fields of strongly varying intensity can lead to artifacts. These can be avoided by inverting for subregions of roughly homogeneous intensity. We conclude that local methods can be of great service even if global high-quality data are available. (Received September 15, 2014)

1106-86-2049 **Yanhua O. Yuan*** (yanhuay@princeton.edu), 308A Guyot Hall, Princeton, NJ 08544, and **Frederik J Simons** and **Ebru Bozdağ**. *Full-waveform adjoint tomography based on wavelet multiscale analysis.*

We present a multiscale scheme for full-waveform adjoint tomography based on a (bi)orthogonal wavelet transform. We show that convergence and stability of the inversions are greatly improved when data and synthetics are progressively presented to the algorithms in a constructive multiscale approximation. Within the industry-standard elastic Marmousi model, we applied the multiscale approach successfully to the body waves generated. In this talk, we also explore the sensitivity of surface waves in waveform-difference tomography. The incorporation of surface waves escalates the cycle-skipping problems compared to inversions considering body waves only. An envelope-based misfit function designed in a multiscale framework is shown to get rid of the numerous local minima present in the waveform-difference misfit surface. The effect of incorrect density information on elastic inversions is also discussed. Based on our analyses and numerical experiments, we ultimately formalize a flexible scheme for full-waveform inversion including body and surface waves, considering density, compressional-wave and shear-wave speed. Ours is a scheme that can be applied to exploration problems, global-scale tomography, as well as to small-scale inversion problems in geoengineering. (Received September 15, 2014)

90 ► *Operations research, mathematical programming*

1106-90-183 **Ram U. Verma** and **Youngsoo Seol*** (y_s40@txstate.edu), 601 University Rd, San Marcos, TX 78666. *Some Sufficient Efficiency Conditions in Semiinfinite Multiobjective Fractional Programming Based on Exponential Type Invexities.*

First a generalization to the first order exponential Hanson-Antczak type invexities to the case of the Hanson-Antczak-type-V-invexities is introduced, which encompasses most of the exponential type invexities as well as other various invexity variants in the literature. Then a number of parametric sufficient efficiency results under various Hanson-Antczak-type generalized-V-invexity assumptions for the semiinfinite multiobjective fractional programming problems are investigated. The obtained results are new and general in nature to challenging applications arising from semiinfinite multiobjective fractional programming and optimization. (Received August 05, 2014)

1106-90-187 **R. N. Mohapatra*** (ram.mohapatra@ucf.edu), Department of Mathematics, University of Central Florida, Orlando, FL 32816, and **R. U. Verma** (r_v124@txstate.edu), Department of Mathematics, Texas State University, San Marcos, San Marcos, TX 78666. *Generalized Hybrid Invexities with Second-Order Parametric Optimality Criteria for Discrete Minmax Fractional Programming.*

First, a class of second order hybrid $(phi, zeta, rho, theta, m)$ invexities is introduced, and then a set of second-order parametric necessary optimality conditions are obtained. Different sets of second-order sufficient optimality conditions for a discrete minmax fractional programming problem using various second-order hybrid invexity assumptions are established. These classes not only generalize many known generalized invexities in the literature, but also are more suitable for applications. (Received August 06, 2014)

1106-90-191 **Ram U. Verma*** (verma99@msn.com). *Higher Order Parametric Optimality Conditions for Discrete Minmax Fractional Programming.* Preliminary report.

This presentation is intended to establish a set of generalized second order parametrically necessary optimality conditions and several sets of higher order sufficient optimality criteria for a discrete minmax fractional programming problem applying various generalized second order hybrid invexity constraints. These new generation hybrid invexities encompass most of the existing notions of generalized invexities in the literature. (Received August 07, 2014)

1106-90-344 **Sinan Aksoy**, **Alexander Adam Azzam**, **Chaya Coppersmith**, **Julie Glass**, **Gizem Karaali*** (gizem.karaali@pomona.edu), **Xueying Zhao** and **Xinjing Zhu**. *School Choice as a One-Sided Matching Problem: Cardinal Utilities and Optimization.*

The school choice problem concerns the design and implementation of matching mechanisms that produce school assignments for students within a given public school district. Here, we explore a class of one-sided, cardinal utility maximizing matching mechanisms focused exclusively on student preferences. We adapt a well-known combinatorial optimization technique (the Hungarian algorithm) as the kernel of this class of matching mechanisms. We find that, while such mechanisms can be adapted to meet desirable criteria not met by any previously employed mechanism in the school choice literature, they are not strategyproof. (Received August 24, 2014)

1106-90-731 **Amir Ali Ahmadi*** (a_a_a@princeton.edu), Operations Research and Financial Eng., Princeton University, NJ , and **Anirudha Majumdar**, MIT, Cambridge, MA. *New Algebraic Relaxations for Polynomial and Discrete Optimization.*

Sum of squares (SOS) programming is a powerful algebraic technique for producing semidefinite programming relaxations for a wide range of NP-hard problems in continuous and discrete mathematics. In this talk, we present our recent frameworks of “DSOS and SDSOS Programming”, which are more tractable alternatives to SOS programming, relying on linear or second order cone optimization. We focus on the applications of these tools to problems in discrete optimization. (Received September 05, 2014)

1106-90-971 **Gwen Spencer*** (gspencer@smith.edu). *Missing Constraints: Local Incentives May Sabotage Landscape-Scale Coordinated Management.*

A rule of thumb in optimization is that the more decisions which can be coordinated, the better. Is this principle suitable for considering problems in landscape-scale natural resource management? When jurisdiction is fragmented, and local land managers face substantial personal costs under globally optimal policies, implementation of “scientifically optimal policies” may be impossible. As an example, we discuss the case of improving preventive fuel reduction policies (to suppress wildfire spread). Can we move towards a richer set of constraints that reflect the true social-ecological nature of managing important natural resource systems? We open this inquiry by extending work in behavioral and environmental economics on conditional provision for the public good to heterogeneous networks. When knowledge that the global system will benefit is not enough to influence local adoption, what can we learn about optimal ways to coordinate an extended landscape of self-interested decision makers? Departures from the theoretical work on the spread of innovation and contagion are substantial, as total adoption is no longer submodular. (Received September 09, 2014)

1106-90-1179 **Zach Feinstein*** (zfeinstein@ese.wustl.edu) and **Birgit Rudloff**. *Computation of Dynamic Multivariate Risk Measures and a Relation to a Set-Valued Bellman's Principle.*

A method for calculating multi-portfolio time consistent multivariate risk measures in discrete time is presented. Market models for d assets with transaction costs or illiquidity are considered on a finite probability space. The set of risk compensating portfolio vectors at each time and state is calculated recursively backwards in time along the event tree. We motivate why the proposed procedure can be seen as a set-valued Bellman's principle. We give conditions under which the backwards calculation reduces to solving a sequence of linear, respectively convex vector optimization problems. Numerical examples include superhedging under illiquidity, the entropic set-valued risk measure, and the composed set-valued average value at risk. (Received September 11, 2014)

1106-90-1221 **Feng Shi*** (bill10@uchicago.edu). *Modeling and Predicting Evolution of Networks.*

Since complex networks are found ubiquitous across disciplines including social, biological and physical sciences, significant attention has focused on their formation and evolutionary dynamics. We present studies on two special dynamics: one coevolves with network topology and the other drives the evolution of higher-order interactions. We study an abstract mathematical model (evolving voter model) for networks in which the evolution of the network topology is tied to the states of the nodes and vice versa. Based on previous results, we show that our model displays many real-world features such as fragmentation and small-world properties. Moreover, we find a family of quasi-stationary distributions of node states, which determines the final state of the network and yields a phase transition in the dynamics. In another study, we propose a hypergraph model for a class of networks featuring interactions that can involve more than two nodes, e.g., group interactions, co-authorships, etc. We develop a statistical model for its evolution, and by fitting this model to millions of published articles in biomedical fields we successfully predict new hyperedges formed every year. This framework provides a machinery to quantitatively study real networks with higher-order interactions. (Received September 11, 2014)

1106-90-1305 **P.Q. Khanh*** (pqkhanh@hcmiu.edu.vn), International University, Linh Trung, Thu Duc, Hochiminh City, Hochiminh 848, Vietnam. *Higher-order Kuhn-Tucker optimality conditions for set-valued optimization with nonsolid ordering cones.*

In this paper, we consider higher-order Kuhn-Tucker optimality conditions in terms of radial derivatives for set-valued optimization with nonsolid ordering cones. First, we develop sum rules and chain rules in the form of equality for radial derivatives. Then, we investigate set-valued optimization with both ordering cones in the objective and constraint spaces having possibly empty interior. We obtain necessary conditions for quasi-relative efficient solutions and sufficient conditions for Pareto efficient solutions. For the special case of weak efficient solutions, we receive even a necessary and sufficient condition. Our results are new or improve recent existing ones in the literature. (Received September 12, 2014)

1106-90-1448 **Jose Yunier Bello Cruz*** (yunier@impa.br), 103-1955 Pacific Court, Kelowna - V1Y8B3, BC, Kelowna, V1Y 8B3, Canada, and **T.T.A. Nghia**. *On Proximal Forward-Backward Splitting Method for Convex Optimization Problems.*

In this talk we focus on the convergence analysis of the proximal Forward-Backward splitting method for solving nonsmooth optimization problems in Hilbert spaces, when the objective function is the sum of two convex functions. Assuming that one of the function is Gâteaux differentiable, whose Gâteaux derivative is supposed to be uniformly continuous on bounded sets and using two new linesearches, the weak convergence is established. Using linesearch in the proximal Forward-Backward splitting iteration, we allow long stepsizes employing more information available at each iteration. Moreover the weak convergence is proved without Lipschitz continuity assumption, getting back the optimal complexity of the iterates when the stepsizes are bounded below. We also analyze a fast version with linesearch improving the complexity of the iterates preserving the optimal complexity of this kind of variants. Furthermore, we present an image restoration problem, illustrating the applicability of the linesearches in the absence of the Lipschitz continuity assumption. (Received September 13, 2014)

1106-90-1609 **Darinka Dentcheva*** (darinka.dentcheva@stevens.edu), Department of Mathematical Sciences, Stevens Institute of Technology, Hoboken, NJ 07030. *Distributed augmented Lagrangian method with applications to stochastic programming.*

A novel distributed method for convex optimization problems with a certain separability structure is presented. The method is based on the augmented Lagrangian framework. We analyze its convergence and provide numerical comparison to other known decomposition methods. Special attention will be placed on the application of the method to several types of stochastic programming problems. (Received September 14, 2014)

1106-90-1612 **Andrzej Ruszczynski*** (rusz@business.rutgers.edu), Rutgers University, Department of Management Sci. and Inf. Sys., 100 Rockefeller Road, Piscataway, NJ 08854. *Alternating Minimization for Structured Optimization.*

We adapt the alternating linearization method for proximal decomposition to structured nonsmooth optimization problems, in which the objective function is a sum of several components, each of which is easier to optimize. The method is related to two well-known operator splitting methods, the Douglas–Rachford and the Peaceman–Rachford method, but it has descent properties with respect to the objective function. This is achieved by employing a special update test, which decides whether it is beneficial to make a Peaceman–Rachford step, any of the possible Douglas–Rachford steps, or none. The convergence mechanism of the method is related to that of bundle methods of nonsmooth optimization. We also discuss implementation for very large generalized lasso problems problems, with the use of specialized algorithms and sparse data structures. We present numerical results for several real-world examples, including a three-dimensional fused lasso problem, which illustrate the scalability, efficacy, and accuracy of the method. Finally we discuss extensions to nonconvex structured optimization. (Received September 14, 2014)

1106-90-1824 **Henry Wolkowicz*** (hwolkowicz@uwaterloo.ca), Dept. of Comb. and Opt., University of Waterloo, Waterloo, Ontario N2L 3G1, Canada. *Taking Advantage of Degeneracy in Cone Optimization: with Applications to Sensor Network Localization.*

The elegant theoretical results for strong duality and strict complementarity for linear programming, LP, lie behind the success of current algorithms. However, the theory and preprocessing techniques that are successful for LP can fail for cone programming over nonpolyhedral cones.

Surprisingly, many important applications of semidefinite programming, SDP, that arise from relaxations of hard combinatorial problems are degenerate. (Slater's constraint qualification fails.) This includes relaxations for problems such as the: Quadratic Assignment; Graph Partitioning; Set Covering and partitioning; and sensor network localization and molecular conformation. Rather than being a disadvantage, we show that this degeneracy can be exploited. In particular, several huge instances of SDP completion problems can be solved quickly and to extremely high accuracy. In particular, we illustrate this on the sensor network localization problem. (Received September 15, 2014)

1106-90-2241 **Yinyu Ye*** (yinyu-ye@stanford.edu), Hunag Engineering Center 308, Stanford, CA 94305. *The Direct Extension of ADMM for Multi-block Convex Minimization Problems is Not Necessarily Convergent.*

The alternating direction method of multipliers (ADMM) is now widely used in many fields, and its convergence was proved when two blocks of variables are alternatively updated. It is strongly desirable and practically valuable to extend ADMM directly to the case of a multi-block convex minimization problem where its objective function is the sum of more than two separable convex functions. However, the convergence of this extension has been missing for a long time — neither affirmatively proved convergence nor counter example showing its failure of convergence is known in the literature. In this paper we answer this long-standing open question: the direct extension of ADMM is not necessarily convergent. We present examples showing its failure of convergence, and propose possible convergent variants. (Received September 16, 2014)

1106-90-2516 **Yipeng Yang*** (yangy@uhcl.edu). *Finite Horizon Time Inhomogeneous Singular Control Problem of One-dimensional Diffusion via Dynkin Game.*

The Hamilton-Jacobi-Bellman equation (HJB) associated with the time inhomogeneous singular control problem is a parabolic partial differential equation, and the existence of a classical solution is usually difficult to prove. In this paper, a finite horizon stochastic singular control problem of one dimensional diffusion is solved via a time inhomogeneous zero-sum game (Dynkin game). The regularity of the value function of the Dynkin game is investigated, and its integrated form coincides with the value function of the singular control problem. We provide conditions under which a classical solution to the associated HJB equation exists, thus the usual viscosity solution approach is avoided. We also show that the optimal control policy is to reflect the diffusion between two time inhomogeneous boundaries. For a general terminal cost function, we showed that the optimal control involves a possible impulse at maturity. (Received September 16, 2014)

1106-90-2525 **Ilbin Lee**, **Marina A Epelman*** (mepelman@umich.edu), **H Edwin Romeijn** and **Robert L Smith**. *Countably-infinite linear programming approaches and simplex-type algorithms for Markov Decision Processes.*

Countably-infinite linear programs (CILPs) are linear programs with countably-infinite number of variables and constraints. They are challenging to analyze or solve since useful properties of finite LPs fail to extend to general CILPs. However, for some structured CILPs, e.g., ones arising as formulations of Markov Decision Processes (MDPs) with countably infinite state spaces, we show that duality, complementary slackness, and a simple analytical representation of extreme points extend to the countably infinite case. In addition, we suggest a simplex-type algorithm for such CILPs and prove its convergence to optimality. Each iteration requires only finite computation, so the algorithm can be used as an iterative solution method for MDPs with countably infinite state spaces. Previous solution methods for such MDPs involved solving finite-state truncations, or estimating the reward function for a finite subset of states. Sequences of MDP policies produced by these methods as the number of states considered increases converge to optimality in value, but convergence may not be monotonic. In contrast, our simplex-based method generates improving policies at each iteration — a desirable feature. Time permitting, we will discuss other types of infinite MDPs amenable to such analysis. (Received September 16, 2014)

1106-90-2842 **Marta Cavaleiro** and **Farid Alizadeh*** (farid.alizadeh@rutgers.edu), 100 Rockafellar Rd, room 5142, Piscataway, NJ 08854. *A Branch and bound algorithm for k-Min-Ball problem.*

The k-min-ball problem asks for finding the smallest ball containing at least k of n given points in general d-dimensional Euclidean space. This problem is NP-hard. The minimum ball problem (requiring the ball contain *all* points) is expressible as a second order cone program (SOCP). However, it turns out that for this special problem there are both primal and dual iterative algorithms that are very similar to the simplex method for linear programming. We incorporate these methods into a branch and bound search to solve the k-min-ball problem. Both the algorithm and computational results, as well as applications in classification theory will be presented. (Received September 16, 2014)

91 ► Game theory, economics, social and behavioral sciences

1106-91-127 **Sara Reed*** (sara.reed@my.simpson.edu), **Levi Boxell** (levi_boxell@taylor.edu), **Yihang Du** (duy@lafayette.edu), **Jeffrey Liebner** (liebnerj@lafayette.edu) and **Julie Smith** (smithjk@lafayette.edu). *Finding NAIRU.*

The non-accelerating inflationary rate of unemployment (NAIRU) is a fundamental concept in macroeconomics. Defined as the rate of unemployment at which the inflationary rate does not change, NAIRU is widely used by policymakers to help determine fiscal and monetary policy. However, NAIRU presents a challenge in that one cannot directly observe NAIRU in the same manner that one can observe the unemployment rate. This challenge also makes it difficult to determine how accurate one's estimates of NAIRU are. In our approach to estimate NAIRU, we employ various univariate smoothers and filters in order to extract the underlying trend from the cyclical unemployment rate. We also use a state-space model and the Kalman Filter along with an EM Algorithm to extract the unobserved state of NAIRU. We expand upon current methods used to estimate NAIRU by utilizing a more general multivariate autoregressive state-space model (MARSS) that incorporates structural changes in the labor market. When assessing the predictive ability of our estimates of NAIRU using the Phillips curve, we find that our estimates perform as well or better than those provided by the Congressional Budget Office. (Received July 25, 2014)

1106-91-862 **Bernard P Brooks*** (bpbsma@rit.edu), 85 Lomb Memorial Dr, Rochester, NY 14623, and **M Radin** and **T Wiandt**. *Global Stability in a Discrete Competitive Two Harvester System.*

A system of coupled difference equations is used to model the interaction between humans and their natural island environment. The two human populations differ in their harvesting and reproductive rates. They compete for a finite natural resource whose growth rate is logistic. Each population can coexist stably with the natural environment in the total absence of the other type of human. Thus there exist two equilibria of the coupled three difference equation system; one with only the high-rate harvesters and one with only the low-rate harvesters. It will be shown that the equilibrium with only high-rate harvesters is stably resistant to invasion from low-rate harvesters whereas the equilibrium with only low-rate harvesters is unstable and susceptible to an invasion of high-rate harvesters. In the end greed wins. (Received September 17, 2014)

1106-91-1063 **Worku T Bitew*** (biteww@farmingdale.edu), 2350 Broadhollow Rd, Farmingdale, NY 11735, and **Wisdom Akpalu**. *Optimum reserve size, fishing induced change in carrying capacity, and phenotypic diversity.*

Fish stocks around the world are heavily overexploited in spite of fishing policies in several parts of the world designed to limit overfishing. Recent studies have found that the complexity of ecological systems and the diversity of species, as well as negative impact of fishing activities on environmental carrying capacity of fish stocks–all contribute to the problem. A number of biologists, managers, and practitioners strongly support the use of marine reserves as a management strategy for marine conservation. This paper contributes to this line of research by seeking an optimum reserve size and fishing effort for situations where species diversity decrease at fishing grounds and fishing activities impact carrying capacity. We found that a reserve size which maximizes economic rents could ruin a fish stock if fishing impacts are not accounted for. On the other hand, the reserve serves as a bifurcation term which could improve the resilience of a marine ecosystem. Keywords: marine reserve;

fishing impact on carrying capacity; fishing policy; phenotypic diversity; stock collapse (Received September 10, 2014)

1106-91-1097 **Kristina B Hilton*** (khilton@mail.usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, Tampa, FL 33620-5700, and **Gangaram S Ladde** (gladde@usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, Tampa, FL 33620-5700. *Collective Behavior of Multi-Cultural Social Networks Under Stochastic Structural Perturbations.* Preliminary report.

Using Lyapunov type functions in combination with comparison methods, we explore the cohesion and invariance among subgroups of a dynamic multi-cultural social network under internal and external random environmental perturbations. In doing so, we look to better understand the behavior of members of various subgroups and how environmental and structural influences may cause a transition from one subgroup to another subgroup of the network as well as the degree to which a subgroup is susceptible to infiltration by other members of the network. The presented work is centered around the decomposition of state domain of dynamic of the cultural community. We characterize the magnitudes of both the intra- and inter- relative cultural affinities with respect to the presented decomposition. We outline a specific illustration that serves to establish the framework in which explicit sufficient conditions for the state decomposition are given in terms of the system parameters. The developed conditions are utilized to describe the asymptotic behavior of self-invariant and conditionally invariant sets and its interpretations. (Received September 10, 2014)

1106-91-1172 **Dawna C Jones*** (djones3@math.fsu.edu), 208 Love Building, 1017 Academic Way, Tallahassee, FL 32306. *Heterogeneous Lucas Asset Pricing with Adaptive Learning.* Preliminary report.

The standard general equilibrium asset pricing models typically undertake two common assumptions of homogeneous agents and rational expectations equilibrium. However, this context sometimes yields outcomes that are inconsistent with the empirical findings. That is, if the agents are perfectly rational then it proves difficult to implement a model that violates the no-trade theorems. As such, we have sought to implement an artificial asset market where the agents are, instead, boundedly rational, utility maximizing, infinitely lived and forward looking. When agents are out of equilibrium, they will simultaneously solve their decision rules along with predictive pricing functions at each time period. Also, the agents will be endowed with constant gains, stochastic gradient and recursive least square adaptive learning schemes to learn the true motions of the pricing functions.

We analyse the implementation of adaptive learning in a Lucas asset pricing model with heterogeneous agents. We focus on the sensitivity of the initial conditions and the convergence of the model to the general equilibrium.
(Received September 11, 2014)

1106-91-1213 **Dane Taylor*** (taylordr@live.unc.edu). *WTM maps for complex contagion on noisy geometric networks.*

Social and biological contagions are often strongly influenced by the spatial embedding of networks. In some cases (e.g., Black Death), contagions spread as a wave through space. In many modern contagions, however, long-range edges (e.g., due to airline transportation or communication media) allow clusters of a contagion to arise in distant locations. We study these competing phenomena for the Watts threshold model (WTM) of complex contagions on empirical and synthetic noisy geometric networks, which are networks that are spatially–embedded on a manifold and consist of both short-range and long-range edges. Our approach involves constructing WTM maps that use multiple contagions to map the nodes as a point cloud, which we analyze using tools from data topology and homology. Importantly, for contagions predominantly exhibiting wavefront propagation, we often identify a noisy geometric network's underlying manifold in the point cloud, highlighting our approach also as a tool for inferring low-dimensional (e.g., manifold) structure in networks. Our work thereby finds a deep connection between the fields of dynamical systems and nonlinear dimension reduction. (Received September 11, 2014)

1106-91-1346 **Yuanying Guan*** (guany@iun.edu), Department of Mathematics, Indiana University Northwest, 3400 Broadway, Gary, IN 46408. *Health care decision-making in light of prospect theory.*

The prospect theory in behavioral economics describes the way that people make decisions using certain heuristics to evaluate the value of gains and losses instead of the real probabilities of outcomes. In this paper, we apply the prospect theory to some healthcare data in analyzing health care decisions for U.S. population at different

income levels. Furthermore, we explore how the health care reform can possibly affect peoples' health care decisions as well as total social welfare.
(Received September 12, 2014)

1106-91-1488 **Ben G Fitzpatrick*** (bfitzpatrick@lmu.edu), 1 LMU Drive, Mathematics Departmetn, Los Angeles, CA 90045, **Jason W martinez** (martinez@tempest-tech.com), 8939 S Sepulveda Blvd, Suite 506, Los Angeles, CA 90045, **Elizabeth Polidan** (polidan@tempest-tech.com), 8939 S Sepulveda Blvd Suite 506, Los Angeles, CA 90045, and **Kate Angelis** (angelis@tempest-tech.com), 8939 S Sepulveda Blvd Suite 506, Los Angeles, CA 90045. *Mathematical and Computational Modeling of Social Norms and College Drinking.*

College drinking is a problem with severe academic, health, and safety consequences. The underlying social processes that lead to increased drinking activity are not well understood. Social Norms Theory is an approach to analysis and intervention based on the notion that students' misperceptions about the drinking culture on campus lead to increases in alcohol use. In this paper we develop a mathematical model, implemented in MATLAB as an agent-based simulation, to examine college drinking. Students' drinking behaviors are governed by two fundamental processes identity verification and peer influences. Both of these processes lead to drinking behaviors as stuidents interact in small groups over the course of a drinking event. Our simulation results provide some insight into the potential effectiveness of interventions such as social norms marketing campaigns.
(Received September 13, 2014)

1106-91-1586 **David Gamble Sykes*** (dgsykes@uncg.edu) and **Jan Rychtář** (j_rychta@uncg.edu). *A Game Theoretic Approach to Valuating Toxoplasmosis Vaccination.*

The protozoan *Toxoplasma gondii* is a parasite often found in wild and domestic cats, and it is the cause of the disease Toxoplasmosis. More than 60 million people in the United States carry the parasite, and the Centers for Disease Control have placed toxoplasmosis in their disease classification group Neglected Parasitic Infections as one of five parasitic diseases targeted as priorities for public health action. In recent years, there has been significant progress toward the development of a practical vaccine, so vaccination programs may soon be a viable approach to controlling the disease. Anticipating the availability of a toxoplasmosis vaccine, we are interested in determining when cat owners should vaccinate their own pets. We have created a mathematical model describing the conditions under which vaccination is advantageous. Our model can predict the the average vaccination level in the population. We find that there is a critical vaccine cost threshold above which no one will use the vaccine. However, a vaccine cost slightly below this threshold results in high usage of the vaccine, and consequently in a significant reduction in population seroprevalence. Not surprisingly, we find that populations may achieve herd immunity only if the cost of vaccine is zero. (Received September 14, 2014)

1106-91-1765 **Matthew J Christen*** (matthew.christen@my.simpson.edu). *Educational Economics.*

I examined how liberal arts colleges could increase revenue from two main sources: tuition and alumni donations. Using data from the US News and World Report and the Integrated Postsecondary Education Data System, I generated a demand curve that can be used to accurately price college tuition. In addition, I generated a simple model that identifies geographical areas from which prospective college students are more likely to travel greater distances for education. Finally, using alumni donation data provided by Simpson College's Office of Advancement, I identified donation patterns that suggest how liberal arts colleges can more efficiently solicit donations from alumni. (Received September 15, 2014)

1106-91-1999 **Danielle Riethmiller*** (danielleriethmiller@sandiego.edu), 5998 Alcala Park, San Diego, CA 92110, and **Samantha Armstrong**. *Strict Hierarchies with the Deegan-Packel Power Index.*

We will analyze the relative power of players as determined by the Deegan-Packel power index in simple voting games. In particular, we investigate which strict hierarchies are achievable with respect to this power index power index. Inspired by previous work with other power indices, we focus particularly on weakly transparent, proper, simple voting games. We show that, under these conditions, any voting game with three to five players cannot have a strict hierarchy with respect to the Deegan-Packel power index. We then use simulation evidence to suggest that any game with more than five players can be constructed to have a strict hierarchy with respect to this index. (Received September 15, 2014)

1106-91-2036 **Eric Lars Sundberg*** (sundberg@oxy.edu) and **Emily Heath**. *Economical extremal hypergraphs for the Erdős–Selfridge theorem.*

A positional game is essentially a generalization of tic-tac-toe played on a hypergraph $(V, \mathcal{H})$. A pivotal result in the study of positional games is the Erdős–Selfridge theorem, which gives a simple criterion for the existence of a Breaker's winning strategy on a finite hypergraph $\mathcal{H}$. It has been shown that the bound in the Erdős–Selfridge theorem can be tight and that numerous extremal hypergraphs exist that demonstrate the tightness of the bound. We call an extremal hypergraph economical if it is n-uniform and Maker has an n-turn winning strategy on that hypergraph. While classifying all extremal hypergraphs for the Erdős–Selfridge theorem is still an open problem, we make progress on this problem by classifying the economical extremal hypergraphs for the Erdős–Selfridge theorem. (Received September 16, 2014)

1106-91-2075 **Eli S. Thompson*** (thompses@miamioh.edu), 219 E. Church St., Oxford, OH 45056, and **Jasmine Everett**. *Neighborhood Size and Memory Effects in a Spatial PD Game.*

Evolutionary Game Theory and the Prisoners Dilemma Game (PD) are commonly used to study the evolution of cooperation. We consider a population of asexually reproducing, age-structured individuals in a two- dimensional square lattice structure. The individuals, either cooperators or defectors, play the PD with their neighbors to accumulate reproductive fitness. We focus on the effects of memory of past interactions, and neighborhood size on the evolution of cooperation. We show that larger neighborhood sizes are detrimental to cooperation. Further, we show that longer memories can hurt the spread of cooperation in small neighborhood sizes. However, for larger neighborhood sizes, longer memories are more favorable for the spread of cooperation than shorter memories. (Received September 15, 2014)

1106-91-2283 **Mike Mesterton-Gibbons** and **Tugba Karabiyik*** (tugbakarabiyik1@gmail.com), Departmant of Mathematics, Florida State University, LOV 208, Tallahassee, FL 32306, and **Tom Sherratt**. *On the evolution of partial respect for ownership: infinite regress revisited.*

An early prediction of game theory was that Bourgeois (B) respect for ownership can arise as an arbitrary convention to avoid costly disputes; but that its opposite, dispute-avoiding anti-Bourgeois (X), through which owners cede their property to intruders, is also an evolutionarily stable state (ESS). Yet first finders of valuable resources are frequently left unchallenged in nature, whereas evidence for the opposite convention is rare at best. An early rationale for this outcome, that two X-strategists would exchange roles repeatedly over many rounds in a costly "infinite regress," was formalized only recently. This analysis showed that if the fighting cost C and probability w of two individuals meeting again exceed thresholds determined by costs of assuming and ceding ownership, then B becomes the only stable convention; but also that infinite regress does not invariably render X unviable. However, the model allowed only for monomorphic ESSs. Here we extend it to allow for polymorphic ESSs, and explore conditions that favor degrees of partial respect for ownership. In particular, we show that X is never uniquely the ESS; and we identify a pathway through which respect for ownership can evolve from disrespect under increasing C and w. (Received September 16, 2014)

1106-91-2381 **Kevin Hutson*** (kevin.hutson@furman.edu), **Michael Berry**, **Tim Chartier** and **Amy Langville**. *Identifying Influential Upsets in College Football.*

Networks model complex systems from a wide range of applications, including contests between teams during a sport season. One of the well-studied aspects of a network is the concept of the most influential or powerful node (team) in the network. The edges (games) of the network can also exert great influence in such measures of node power. In this talk, we propose methods that identify influential edges in a network and their impact on a ranking of nodes as it applies to a college football season. (Received September 16, 2014)

1106-91-2405 **Mitchell Eithun*** (eithunm@ripon.edu), **McKenzie Lamb** and **Andrea Young**. *Modeling* Monopoly *with Monte Carlo Simulations.* Preliminary report.

The board game *Monopoly* is often criticized for its lack of strategy. That is, the game has too many random elements to make the game worthwhile. Using a computer model involving Monte Carlo simulations, we will explore the effects of different *Monopoly* strategies on the outcome and length of the game. By reducing *Monopoly* strategy to a set of parameters, we use optimization techniques such as hill climbing and genetic algorithms to approximate optimal *Monopoly* strategies. Other topics will include the most landed on properties, indicators used to predict game winners, and how changes in upcoming "house rules" edition change the outcome of the game. (Received September 16, 2014)

1106-91-2449 **Peter J. Mucha*** (mucha@unc.edu). *Communities in Multilayer Networks.*

A prominent problem in the application of networks to various disciplines is the algorithmic detection of tightly connected groups of nodes known as communities. Recently, there has been increased interest in networks with multiple types of relationships, that change in time, or that network together multiple kinds of networks. It is important to handle such "multilayer" features appropriately in identifying communities in these networks. We consider the state of community detection in multilayer networks and demonstrate its application with examples from real-world data. (Received September 16, 2014)

1106-91-2664 **Paul D. Olson*** (pdo2@psu.edu), 4205 College Drive, School of Science Complex, Penn State Erie, Erie, PA 16563, and **Landon Chambers**. *Numerical values of specific sequences of Combinatorial Games.*

While working on an undergraduate research project , student Landon Chambers discovered a way to determine the numerical value of several specific sequences of combinatorial games . The talk will describe the sequences of games and display Landon's formula for determining their numerical values . It will also include a proof of the formulas . (Received September 16, 2014)

92 ► Biology and other natural sciences

1106-92-42 **Souvik Bhattacharya*** (souvik.bhattacharya@unitn.it), Via sale No 105, Povo, Trento, Italy, and **Maia Martcheva** and **Xue-Zhi Li**. *A predator-prey-disease model with immune response in infected-prey.*

In this paper, a predator-prey-disease model with immune response in the infected prey is formulated. The basic reproduction number of the within-host model is defined and it is found that there are three equilibria: extinction equilibrium, infection-free equilibrium and infection-persistent equilibrium. The stabilities of these equilibria are completely determined by the reproduction number of the within-host model. Furthermore, we define a basic reproduction number of the between-host model and two predator invasion numbers: predator invasion number in the absence of disease and predator invasion number in the presence of disease. We have predator and infection-free equilibrium, infection-free equilibrium, predator-free equilibrium and a coexistence equilibrium. We determine the local stabilities of these equilibria with conditions on the reproduction and invasion reproduction numbers. Finally, we show that the predator-free equilibrium is globally stable. (Received June 10, 2014)

1106-92-85 **Ranadhir Roy*** (rroy@utpa.edu), 1201 W University Drive, Edinburg, TX. *Unsteady Two-Phase Flow in a Catheterized Artery with Atherosclerosis.*

In this research we investigate the effect of oscillating axisymmetric blood flow on a catheterized artery in the presence of atherosclerosis, which is obtained from the available experimental data. The oscillatory (unsteady) blood flow in the arterial tube is formulated as a two-phase model composing a suspension of erythrocytes (red cells) in plasma. The coupled differential equations for both fluid (plasma) and particles (red cells) are solved by using analytical and computational methods. The important quantities such as plasma speed, velocity of red cells, blood pressure force, impedance (blood flow resistance) and the wall shear stress are computed for different values of the catheter size and hematocrit due to the red cells. We calculate dependence of these quantities on the temporal and spatial variable as well as on the frequency of the flow oscillation and the main parameters of the flow system. We find, in particular, that the higher value of the frequency, larger catheter size, and higher values of hematocrit can lead to higher values of axial velocity, the impedance and the wall shear stress in the stenosis zone. (Received July 07, 2014)

1106-92-220 **Zhilan Feng*** (fengz@purdue.edu), Department of Mathematics, Purdue University, West Lafayette, IN 47907. *Emerging disease dynamics in a model coupling within-host and between-host systems.*

Epidemiological models and immunological models have been studied largely independently. However, the two processes (within- and between-host interactions) occur jointly and models that couple the two processes may generate new biological insights. Particularly, the threshold conditions for disease control may be dramatically different when compared with those generated from the epidemiological or immunological models separately. We developed and analyzed an ODE model, which links an SI epidemiological model and an immunological model for pathogen-cell dynamics. When the two sub-systems are considered in isolation, the dynamics are standard and simple. That is, either the infection-free equilibrium is stable or a unique positive equilibrium is stable depending on the relevant reproduction number being less or greater than 1. However, when the two sub-systems are explicitly coupled, the full system exhibits more complex dynamics including backward bifurcations;

that is, multiple positive equilibria exist with one of which being stable even if the reproduction number is less than 1. The biological implications of such bifurcations are illustrated using an example concerning the spread and control of toxoplasmosis. (Received August 31, 2014)

1106-92-239 **Natali Hritonenko*** (nahritonenko@pvamu.edu), Department of Mathematics, P.O. Box 519, Prairie View, TX 774, TX 77446-0519, and **Yuri Yatsenko**, 7502 Fondren Road, Houston, TX 77074. *Sustainable strategies of environmental protection: modeling and optimization.* Preliminary report.

Environmental disasters intermit our well-being; thus, it is important for the human population to be prepared (adapted) to deal with hurricanes, fires, tornadoes, and other catastrophes. Furthermore, the fast-growing world requires an increase in industrial and agricultural manufacturing, which contributes to environmental contamination. To decrease the pollution level (mitigate) is currently one of the world's top priorities. A considered economic-environmental model aims to investigate a rational investment to environmental mitigation and adaptation, which is an important issue in designing long-term environmental policies and regulations on both international and national levels. A qualitative analysis of the model demonstrates the existence of a unique steady state and leads to determining the optimal balance between investing into adaptation measures and emission abatement depending on a country development level and its contribution to a global pollution stock. The model is calibrated on the available economic and climate data and predictions. Further directions and open questions are also highlighted. (Received August 13, 2014)

1106-92-254 **Jan Rychtar*** (rychtar@uncg.edu), Department of Mathematics and Statistics, Greensboro, NC 27412, and **Mark Broom**. *Habitat selection game in structured populations.*

The important biological problem of how groups of animals should allocate themselves between different habitats has been modelled extensively. Such habitat selection models have usually involved infinite well-mixed populations. In particular the problem of allocation over a number of food patches when movement is not costly, the ideal free distribution (IFD) model is well-developed. Here we generalize (and solve) a habitat selection game for a finite structured population. We show that habitat selection in such a structured population can have multiple stable distributions (in contrast to the equivalent IFD model that is practically unique). We also define and study a "predator dilution game" where unlike in the habitat selection game, individuals prefer to aggregate (to avoid being caught by predators due to the dilution effect) and show that this model has a unique solution when movement is unrestricted. (Received August 15, 2014)

1106-92-280 **Eric A Eager***, eeager@uwlax.edu. *Modeling and Analysis of Disturbance Specialist Plants.*

Disturbance specialist plants are plants whose seeds, roughly speaking, only germinate in disturbed soil. Soil disturbances often occur in very unpredictable ways, both in time and space, necessitating the use of stochastic models when studying their population dynamics. In this talk we introduce a stochastic integral projection model for a disturbance specialist plant population and its seed bank. We show that the mean intensity of disturbance affects the long-term viability of the plant - seed bank population in different ways, depending on the strength of the "storage" effect in the seed bank. We explore the effects of age structure and autocorrelated disturbances on this result. (Received August 19, 2014)

1106-92-293 **Ruscena Wiederholt*** (rwiederholt@email.arizona.edu), 325 Biological Sciences East, University of Arizona, 1311 E 4th St, Tucson, AZ 85721, and **Laura Lopez-Hoffman**, **Brady Mattson**, **Waynge Thogmartin**, **Jay E Diffendorfer**, **Richard A Erickson** and **Paula Federico**. *Estimating the contributions of discrete habitats to population dynamics of migratory species.*

The ability to assess the relative demographic contributions of discrete habitats to the population dynamics of migratory species is critical for both ecology and management and conservation applications. Metrics for assessing habitat contributions have been well-developed for metapopulations, but less studied for migratory populations that have seasonal, directed movements between habitats. We developed a quantitative framework for estimating the demographic contributions of the discrete habitats used by migratory species during their annual cycle. Our framework accounts for seasonal movements between multiple breeding and nonbreeding habitats. We tested our framework on a hypothetical species migrating between two- and three-habitat networks. We found that habitat-specific contributions are dependent on habitat-specific survival rates and the portion of the population that migrates. These metrics are also spatially linked (e.g. reduced survival in one habitat also decreases the contribution metric in other habitats). Our contribution framework represents an expansion of theory on the dynamics of spatiotemporally structured populations to migratory species and a new quantitative method for identifying habitats that are important for migratory species conservation. (Received August 19, 2014)

1106-92-302 **Eric A Eager***, eeager@uwlax.edu, and **Richard A Erickson** and **Wayne E Thogmartin**. *Modeling and analysis of avian populations vulnerable to wind energy.*

Alternative energy sources such as solar and wind hold the potential to produce electricity without burning fossil fuels. These energy sources offer the advantage of decreasing greenhouse gas emissions and other types of pollution when compared to energy produced from fossil fuels. Because of this, the U.S. has placed a high priority on generating electricity from wind turbines. Despite these benefits, wind energy development may incur environmental costs such as wildlife (e.g avian) mortality. Species may be vulnerable to mortality because of both collision risk and their unique life history. In this talk we present a general branching process model for the risk of extinction for various avian populations as a function of the "take" associated with various levels of wind energy infrastructure and life history. We show that, expectedly, an increase in wind energy infrastructure increases the extinction risk of a given population. Additionally, we show that an increase in time-to-reproduction also increases the extinction risk of a given population. We explore the implications of these results from the perspective of biological conservation. (Received August 20, 2014)

1106-92-373 **Sunnie Joshi*** (sjoshi@temple.edu), 1523 Green Street, Unit 1, Philadelphia, PA 19130. *Estimating Residual Stresses in Arteries by an Inverse Spectral Technique.*

It is known that residual stresses play a significant role in determining the overall stress distribution in soft tissues. A mathematical model is studied to estimate residual stress field in the arterial wall by making use of intravascular ultrasound (IVUS) imaging techniques. The arterial wall is modeled as a nonlinear, isotropic, slightly compressible elastic body. A boundary value problem is formulated for the residually stressed arterial wall, the boundary of which is subjected to a quasi-static blood pressure, and then an idealized model for the IVUS interrogation is constructed by superimposing small amplitude time harmonic infinitesimal vibrations on large deformations. The analysis leads to a system of second order differential equations with homogeneous boundary conditions of Sturm-Liouville type. By making use of the classical theory of inverse Sturm-Liouville problems, and root finding and optimization techniques, an inverse spectral algorithm is developed to approximate the residual stress distribution in the arterial wall, given the first few eigenfrequencies of several induced blood pressures. (Received August 25, 2014)

1106-92-387 **Jane Ivy Coons*** (janeivycoons@gmail.com) and **Joseph Rusinko**. *Combinatorics of k-Interval Cospeciation for Cophylogeny.*

We show that the cophylogenetic distance, k-interval cospeciation, is distinct from other metrics and accounts for global congruence between locally incongruent trees. The growth of the neighborhood of trees which satisfy the largest possible k-interval cospeciation with a given tree indicates that k-interval cospeciation is useful for analyzing simulated data. (Received August 26, 2014)

1106-92-421 **James P Peirce*** (jpeirce@uwlax.edu), La Crosse, WI 54601, and **Greg Sandland**, **Barbara Bennie** and **Mary O'Driscoll**. *Modeling and analysis of a temperature-driven outbreak of waterfowl disease in the Upper Mississippi River.* Preliminary report.

Bithynia tentaculata is an invasive snail that was discovered in the upper Mississippi River in 2002. In addition to being a threat to native benthos, the snail harbors two parasite species that kill thousands of migrating waterfowl when infected snails are consumed. Both parasite species exhibit temperature-dependent transmission patterns with no transmission occurring when temperatures either fall below or exceed certain thresholds. The transmission window overlaps the waterfowl's seasonal migrations. Using data collected from our empirical work, we developed an annual model for the host-parasite system in which transmission is driven by water temperature.

Running simulations from annual temperature profiles selected from a random distribution, we quantify the dependence of the number of infected hosts to the annual average temperature. As the annual average temperature increases, the prediction intervals for infected populations initially increase, reaching a threshold, after which they decay. Results suggest that warming trends in water temperature may have a positive effect on future uninfected populations. (Received August 27, 2014)

1106-92-451 **Eric Marland*** (marlandes@appstate.edu), **Dawn Woodard**, **Susannah Hogue**, **Maya Hutchins**, **Gordon Buckingham**, **Meredith Branham**, **Jeff Colby** and **Gregg Marland**. *Climate dynamics: the scale of uncertainty.*

In an effort to track carbon flows, researchers have pushed to create higher and higher resolution maps of carbon fluxes, from emission to sequestration. These highly detailed maps may assist in attributing emissions to various parties, verifying treaty agreements, and increasing our understanding of the global carbon cycle.

Multiple attempts to estimate emissions at various spatial scales use various approaches and proxy data sets to derive their estimates. This presentation investigates and characterizes uncertainties in global emissions data, the implications on issues of scale and resolution, and initial approaches for reducing uncertainty. We examine widely-used estimates in a detailed comparison, revealing marked differences at smaller spatial scales. Since over half of the emissions from some countries come from large point sources such as power plants, we also analyze the uncertainty in emissions from these large sources of emissions and outline approaches to characterizing and reducing that uncertainty. The result is an analysis that suggests that the useful working resolution of an emissions data set is closely tied to the spatial uncertainty in large point sources and the nature of the proxy data used in the estimates. (Received August 28, 2014)

1106-92-538 **Matthew H Holden*** (`mhh88@cornell.edu`), Center for Applied Mathematics, Cornell University, 657 Rhodes Hall, Ithaca, NY 14853, and **Stephen P Ellner** and **Jan P Nyrop**. *Optimal time dependent sampling for invasive species management.*

Previous studies on the optimal detection of invasive species have recommended less intense sampling protocols than what is often deployed in the field. However, these suggestions are largely based on the analysis of static strategies, ones that do not change over the course of time, and therefore can underestimate sampling effort during the earliest portion of the management period. Using optimal control theory to minimize the total cost of damage and management, we find that the best detection strategies are characterized by intense early sampling, followed by a sharp decline in sampling effort towards an equilibrium value that should be maintained consistently over the rest of the management period. For such a strategy to greatly reduce costs over the best constant strategies, three conditions must be met: (1) the pest's local spread rate must be much larger than the rate of introduction and establishment from an outside source, (2) the cost of sampling is far cheaper than the cost of local outbreaks and (3) sampling is effective. When these conditions do not hold, time static sampling protocols can provide reasonably cost effective control. (Received September 02, 2014)

1106-92-565 **Michael Kelley*** (`makinnc@gmail.com`), **Bill Bauldry** and **Eric Marland**. *Optimal cycle length for a managed forest.* Preliminary report.

It is well established how to calculate the optimal cycle length for a managed forest if you are interested in maximizing the amount of wood harvested from a forest. However we are typically not interested in maximizing wood, we want to maximize our profit. As offset protocols begin to incorporate the costs of carbon and the time value of emissions, this problem becomes somewhat more complicated. Here we show the development of a model that incorporates these elements and then proves some generalizations. With an optimal cycle time in hand, we then show a simulation based optimization for the transition time between a current cycle and the optimal cycle. To maximize the usefulness of the approach, we outline methods and results for incorporating uncertainty and economic discounting. (Received September 02, 2014)

1106-92-568 **Horst R Thieme*** (`hthieme@asu.edu`), School of Mathematical and Statistical, Sciences, Arizona State University, Tempe, AZ 85287-1804, and **Wen Jin**. *Towards a persistence theory for sexually reproducing structured populations.* Preliminary report.

Persistence of a structured population typically involves a threshold parameter R_0 called the basic reproduction number which separates persistence from extinction.

If the population dynamics are modeled by iterating a map (discrete-time semiflow) and sexual structure or other types of mating are ignored, R_0 typically is the spectral radius of a bounded linear map on a normed vector space that is a first order approximation of the original map at the extinction state. If mating is taken into account, the first order approximation is no longer additive but still a (positively) homogeneous (of degree one) map on the cone of an ordered normed vector space.

For homogeneous map there is an analogy to the spectral radius, called cone spectral radius. The question arises whether the cone spectral radius has similar threshold properties as the usual spectral radius. This is related to the question whether the cone spectral radius is an eigenvalue associated with positive eigenvectors and eigenfunctionals.

Applications are presented for spatially distributed or rank-structured populations that reproduce sexually. (Received September 02, 2014)

1106-92-639 **Laurel A Ohm*** (`laurelohm@gmail.com`). *Supplemental immunization activities: a mathematical model for measles control in Kenya.*

Though sustained progress has been made, measles continues to pose a serious health concern during early childhood in many developing countries. Sub-Saharan Africa alone accounted for nearly 40 percent of measles mortality in 2010 (about 50,000 deaths). Elimination of the disease within the next fifteen to twenty years represents a major goal for the World Health Organization. In this paper, we present an SEIR model for measles transmission in Kenya based on historical and projected demographic data as well as recorded immunization activities. We explore the effects of routine infant vaccination and periodic mass-vaccination campaigns for the under-five population on the persistence of the disease thirty to fifty years into the future. We show that, in the case of Kenya, given a certain level of routine measles vaccination, we can determine the corresponding SIA periodicity and coverage necessary for measles control, allowing for exploration of the tradeoffs in feasibility and cost-effectiveness between sustained routine coverage and periodic SIAs. (Received September 03, 2014)

1106-92-645 **Olivia Brozek** and **Matthew Glomski*** (matthew.glomski@marist.edu), Marist College, Department of Mathematics, 3399 North Road, Poughkeepsie, NY 12601. *A compartmental epidemiological model with infectious-deceased class.* Preliminary report.

We consider *Marburg Hemorrhagic Fever* (MHF), a rare and deadly disease caused by a virus from the same family as *Ebola*. Evidence from outbreaks suggests a vigorous infection pathway from the recently deceased to the living, and for this reason the traditional *susceptible-exposed-infectious-removed* (SEIR) model may not suffice to capture the dynamics at work in MHF epidemics. We extend the SEIR model to include an *infectious-deceased* compartment. This analysis is compared to previous SEIR models for the 2004-2005 MHF outbreak in Uige, Angola. We then adjust the model to include births and non-disease deaths as demographic features in the model. Stability of the disease-free and endemic state equilibria are investigated. Finally, we discuss how this model may apply to the current West African Ebola epidemic. (Received September 04, 2014)

1106-92-674 **Jim M Cushing*** (cushing@math.arizona.edu), Department of Mathematics, University of Arizona, 617 N Santa Rita, Tucson, AZ 85721. *A model for the Darwinian dynamics of an adult-on-juvenile cannibalistic population.* Preliminary report.

I will describe a model for the dynamics of a cannibalistic population whose demographic structure is based on juveniles as victims and two types of adults: cannibals and non-cannibals. Model parameters control the rates at which adults can change from non-cannibal to cannibal (and vice versa). A key assumption is that while cannibalism has an obvious negative effect on juvenile survival, it has a positive effect on adult cannibal survival. Another is that basic vital rates (e.g. the per adult birth rate) depend on the availability of an environmental food resource, which is assumed to be negatively correlated with the rate of cannibalism. The question of interest is whether, and under what circumstances, cannibalism will prevent population extinction in circumstances when environmental change reduces resource availability. An evolutionary version of the model is formulated in order to determine conditions under which cannibalism will be favored by natural selection. This project is motivated by recent observations of marine birds (glaucous winged gulls) on Protection Island National Wildlife Refuge that show a strong positive correlation between rates of egg cannibalism by adults and mean sea surface temperature (an increase in which reduces gull food resources). (Received September 04, 2014)

1106-92-678 **Alexander Galarce*** (alexander.galarce@ncf.edu), New College of Florida, Division of Natural Sciences, 5800 Bay Shore Road, Sarasota, FL 34243-2109, and **Sageanne Senneff** (ssenneff@ucsc.edu), Mathematics Department, UC Santa Cruz, 1156 High Street, Santa Cruz, CA 95064. *A Phenomenological Mathematical Model of a Cardiac Action Potential with Intracellular Calcium Cycling.*

In ventricular cells, intracellular calcium serves as a second messenger that modulates current and electrical potential difference between the interior of the cell and the extracellular space. This regulation is essential to proper cardiac function. We present a numerical model incorporating components from the Bueno-Orovio et al. minimal model of the cell membrane potential and the Shiferaw et al. intracellular calcium model in ventricular myocytes. The combined model is a series of nonlinear differential equations which specify the response of the cell membrane and the intracellular calcium concentration to an electrical stimulus. The model allows voltage to influence calcium through a transmembrane current of calcium ions and allows calcium to affect the closure of ion channels, thereby influencing voltage. The two-way coupling permits the formation of alternans, a period-2 dynamical state, to occur through instabilities in voltage or calcium and can be used to study alternans properties in both cases. (Received September 04, 2014)

1106-92-720 **Pamela B Fuller*** (fullep@rpi.edu), Dept. of Mathematical Sciences, Rensselaer Polytechnic Institute, 110 8th St., Troy, NY 12180, **Gregor Kovacic** (kovacg@rpi.edu), Dept. of Mathematical Sciences, Rensselaer Polytechnic Institute, 110 8th St., Troy, NY 12180, and **David Cai** (cai@cims.nyu.edu), Courant Institute, 251 Mercer St., New York, NY 10012. *Integrate-and-Fire Model of Insect Olfaction.*

When an insect detects an odor, the stimulus triggers a series of synchronous oscillations of the neurons in its antenna lobe. These oscillations are followed by slow dynamical modulation of the firing rates, which continues after the stimulus has been turned off. I model this behavior by using an Integrate-and-Fire neuronal network with excitatory and inhibitory neurons. The inhibitory response of both types of neurons contains a fast and slow component. The fast component, together with the excitation, creates the initial oscillations while the slow component suppresses them and aids in the creation of the slow patters that follow. During the initial oscillations, the stimulus can be identified by determining the specific subset of excitatory neurons that participate consistently in every cycle of the oscillations. I have reduced the model to a mean field model where the excitatory and inhibitory neurons are each considered as a population. Each population has a mean firing rate, so the collection of individual spike inputs is estimated as a slowly varying continuous function. The mean field model strongly agrees with numerical simulations of an all-to-all coupled neuronal network as both produce the proper spike behavior with similar parameter values. (Received September 05, 2014)

1106-92-832 **Azmy S Ackleh*** (ackleh@louisiana.edu), Department of Mathematics, University of Louisiana at Lafayette, Lafayette, LA 70504, and **Jacoby Carter**, **Vinodh Chellamuthu**, **Baoling Ma** and **Tingting Tang**. *A general structured population model with application to amphibians and associated diseases.* Preliminary report.

We present a general class of Susceptible-Infected (SI) structured population models that applies to problems arising in ecology, epidemiology and cell biology. The SI model consists of a system of quasilinear hyperbolic partial differential equations coupled with a system of nonlinear ordinary differential equations. We develop a second-order high-resolution finite difference scheme to approximate the solution of the model. Convergence of the numerical approximations to a weak solution with total bounded variation is proved. This model is then applied to understand the dynamics of amphibians with Chytridiomycosis (an infectious disease implicated in the decline or extinction of many amphibian populations). (Received September 07, 2014)

1106-92-847 **Shanshan Chen** and **Junping Shi*** (jxshix@wm.edu), Department of Mathematics, College of William and Mary, Williamsburg, VA 23187. *Gierer–Meinhardt system with activator production saturation and gene expression time delays.*

Gierer–Meinhardt reaction-diffusion system is one of prototypical models for spatial-temporal pattern formation. The dynamics of Gierer–Meinhardt system with activator production saturation and gene expression time delays is considered here. We analyze (i) bifurcation and pattern formation of non-delay model; (ii) global asymptotic stability for large saturation coefficient; (iii) delay-induced oscillations. (Received September 07, 2014)

1106-92-854 **Victor Barranca*** (barranca@nyu.edu). *Reconstruction of Structural Connectivity in Sparsely-Connected Neuronal Networks Using Compressive Sensing.*

Recovering structural connectivity in large neuronal networks is an unresolved yet fundamental problem in characterizing neuronal computation. Taking into account the prominence of sparsity in neuronal connectivity, we develop a framework for efficiently reconstructing neuronal connections in a sparsely-connected, feed-forward network model with nonlinear integrate-and-fire dynamics. Driving the network with a small ensemble of random stimuli, we derive a set of underdetermined linear systems relating the network connectivity to the firing rates of the downstream neurons. In reconstructing the network connections, we utilize compressive sensing theory to facilitate the recovery of sparse solutions to such underdetermined linear systems. Using the reconstructed connection matrix, we also accurately recover network inputs distinct from the training set of stimuli. We expect this work to be useful in understanding the structure-function relationship for neuronal networks, giving insight into a possible mechanism for unconscious inference of natural stimuli. (Received September 08, 2014)

1106-92-905 **Maeve L McCarthy*** (mmccarthy@murraystate.edu), Mathematics & Statistics, Murray State University, Murray, KY 42071, and **Dorothy Wallace**. *A model of the impact of morphological choice on the Arizona Tiger Salamander.* Preliminary report.

Arizona Tiger Salamanders exhibit facultative paedomorphosis in which the salamander larvae either metamorphose into terrestrial adults, become sexually mature while still in their larval form or become cannibalistic adults. We consider an ODE model of the salamanders and their food sources. Predation is modeled using a modified Hill function that captures the contribution of each prey to the diet of the predator. We discuss the analysis and interpretation of the model. In particular, we investigate the impact of different morphological choices on the system to determine whether a dominant choice drives the population dynamics. (Received September 08, 2014)

1106-92-922 **Marc A Harper** (marc.harper@gmail.com) and **Dashiell Fryer*** (leec@chem.ucla.edu). *Equilibrium Selection for Markov Processes via Random Trajectory Entropy with applications to Finite Population Biology.*

For the Moran process with mutation in multitype populations we show that random trajectory entropy is a measure of instability of stationary extrema, combining information from the stationary distribution and the inherent randomness (entropy rate) of the process. This allows equilibria selection between equilibria of the same process as well as the comparison of processes themselves. Accordingly we find that for a population with many equilibria that the most stable is determined by the population size, mutation rate, and intensity of selection, with each equilibria favored under various parameter combinations. (Received September 08, 2014)

1106-92-924 **Marc A Harper** (marc.harper@gmail.com), **Chris Lee** and **Dashiell Fryer** (Dashiell.Fryer@pomona.edu). *A Powerful Long Memory Strategy for the Prisoner's Dilemma.*

We present a long-history strategy capable of quickly inferring opponent strategies and building coalitions in population games using statistical inference and machine learning techniques. Players using this strategy very effectively invade populations of existing strategies including tit-for-tat, win-stay-lose-shift, and zero determinant strategies, and conversely block invasion by these strategies, even in the presence of substantial ambient noise (errors in play). Many computationally intense simulations yield high-confidence fixation probabilities (analytic results are not easily attainable). This shows that longer memory strategies can be of great utility in population games. (Received September 08, 2014)

1106-92-973 **Olcay Akman**, **Timothy Comar** and **Daniel Hrozencik*** (dhro@att.net), Mathematics Department, HWH 332, Chicago State University, Chicago, IL 60628. *Constructing Stable Stochastic Gene Regulatory Networks via Genetic Algorithms.* Preliminary report.

Our goal is to construct a Boolean gene regulatory network model using genetic algorithms with minimum variation in state transition probabilities that control the changes between the attracting and non-attracting states. We also attempt to determine the stochastic variable types and boundaries rendering some states highly attracting. (Received September 09, 2014)

1106-92-1076 **David Murrugarra*** (murrugarra@uky.edu), Mathematics Department, University of Kentucky, Lexington, KY 40506-0027. *Optimal Control Methods for Stochastic Gene Regulatory Networks.*

One of the main goals of computational biology after the post-genomic era is to develop optimal control strategies to find efficient medical treatments for changing the state condition of a cell into a new desirable state. The state of a cell is commonly modeled as a Gene Regulatory Network (GRN) which determines the interaction between the different genes involved in an specific cell function. In this context, given a GRN, the possible control actions can be represented as manipulation of nodes and edges of the GRN. Node manipulation requires technology to completely repress or fully activate a particular gene product while edge manipulations only requires a drug that inactivate the interaction between two gene products, which is a realistic control action for medical treatment. The combination of the two possible actions, node and edge manipulations, may produce more effective control strategies for realistic GRNs currently available. For this talk, having a set of intervention targets represented by control nodes and edges, optimal control algorithms for the identification of the best combination of control targets will be discussed. This talk will also focus on algebraic tools for identifying potential intervention targets. (Received September 10, 2014)

1106-92-1080 **Erica J. Graham*** (ejgraha2@ncsu.edu) and **James F. Selgrade**. *Modeling the dynamics of insulin-mediated ovarian steroid production.*

The ovulatory cycle is a tightly regulated system of feedback that depends largely on cross-talk between brain- and ovary-derived hormones. Polycystic ovary syndrome (PCOS), a common cause of infertility, results from dysregulation of these hormones and is often characterized by increased ovarian androgen production (hyperandrogenism). Hyperandrogenemic PCOS is also associated with elevated insulin levels resulting from cellular insulin resistance (an important mediator of type 2 diabetes). Although the precise mechanisms of ovulatory dysfunction in PCOS remain to be elucidated, we can explore its pathogenesis through mathematical modeling of known endocrine processes. Here, we develop a system of nonlinear ordinary differential equations to describe follicle development and intracellular mechanisms of insulin-mediated ovarian steroid production. We estimate a typical set of parameters by optimizing the model with data obtained from the literature and present numerical results. We then explore abnormal parameter regimes and discuss implications for the role of insulin in ovulatory dysfunction. (Received September 10, 2014)

1106-92-1103 **K. Harrison Holmes*** (khholmes@asu.edu), **Perry Olliver**, **Naomi M. Pier** and **John D. Nagy**. *Modeling an Experimental Analog to Metapopulation Dispersal.* Preliminary report.

Dispersal dynamics are a natural focus when researching metapopulations. However, dispersal parameters are difficult to pin down, even when modeling well-known metapopulations like that of American pikas (*O. princeps*) residing in discrete ore patches in Bodie, California. Andrew Smith and members of our lab have studied the Bodie pikas for decades, resulting in one of the strongest ecological data sets available. To improve current estimates for dispersal parameters, we have developed an experimental metapopulation of confused flour beetles (*T. confusum*), comprising discrete flour habitats connected by tubes to allow for movement among patches. We expect that experimentally verified models of *T. confusum* dispersal may later prove analogous to other systems, including that of Bodie. Here we show that dispersal is linear with respect to density and therefore innate, in that beetles actively seek out new habitat as opposed to simply blundering into patches. This informs the construction of a model in which Dennis *et al.*'s LPA (larvae, pupae, adults) equations govern individual patches, whereas innate dispersal governs movement among patches. The model performs well against dispersal trials performed in the experimental system over several months. (Received September 10, 2014)

1106-92-1125 **Emily Hunt** and **Anthony Tongen*** (tongenal@jmu.edu). *A Periodic Matrix Population Model for Monarch Butterflies.* Preliminary report.

The monarch butterfly (*Danaus plexippus*) exhibits a unique migration phenomenon leaving Michoacán, Mexico in the spring and traveling as far north as Southern Canada; later generations return to the same location in Mexico the following fall. However, there is concern within the scientific community about the long-term stability of this impressive annual journey. We use periodic population matrices to model the life cycle of the eastern monarch butterfly and find that this unique migration is not currently at risk. We extend the model to address the three primary obstacles for the long term survival of this unique migration: deforestation in Mexico, increased extreme weather patterns, and milkweed degradation. (Received September 10, 2014)

1106-92-1127 **Jia Zhao*** (zhaojiachina@gmail.com), 1523 Greene Street, Room 411, Columbia, SC 29208, and **Qi Wang**, 1523 Greene Street, Room 411, Columbia, SC 29208. *3D Mathematical Modeling and Simulations of Cell Mitosis by a Phase Field Approach.* Preliminary report.

During a cell cycle, mitosis is a process, in which a mother cell duplicates into two generically similar daughter cells. In the initial stage of mitosis, the mother cell, attached on a substrate, would undergo a dramatical shape change by detaching from the substance and forming a round surface. At the late stage of mitosis, a contractile ring would form in cell orbit and the mother cell would split into two daughter cells, which is known as cytokinesis for eukaryotic cells.

Recently, we have developed a series of three-dimensional hydrodynamic models by a phase field approach, studying cellular mitosis. Qualitatively patterns of cell rounding, blebbing and division process have been observed. In this talk, our study on the mechanism and controlling factors of cell mitosis would be present. 3D numerical simulations will be shown, as well. (Received September 10, 2014)

1106-92-1131 **David B Damiano** and **Melissa R McGuirl*** (mrmcgu15@g.holycross.edu). *The Topological Microstructure of Murine Tumors.* Preliminary report.

Using methods of computational topology, we have developed a new method of analysis of CT-SPECT images of experimentally induced solid tissue tumors in mice. Using concepts from Morse theory, we extract and analyze critical points on each image, and represent each tumor image by labeled contour trees. Leaf and branch lengths are determined either by changes in intensity or volume between critical values. To quantify the differences between treated tumors and control-group tumors we utilize a phylogenetic metric, principal component analysis, and k-means clustering on the collection of binary tree representations of the images. With these methods we are able to distinguish treatment and control groups, and identify structural differences between the tumors in these groups. Algorithmic development was carried out in MATLAB. Mouse images and image extraction software have been provided courtesy of inviCRO. (Received September 16, 2014)

1106-92-1141 **Abdul-Aziz Yakubu*** (ayakubu@howard.edu), Mathematics Department, Howard University, 2441 6th Street NW, Washington, DC 20059, and **Avner Friedman** (afriedman@math.osu.edu). *Anthrax epizootic and migration: Persistence or extinction.*

In this talk, we will use an extension of the deterministic anthrax epizootic mathematical model of Hahn and Furniss to study the effects of anthrax transmission, carcass ingestion, carcass induced environmental contamination, and migration rates on the persistence or extinction of animal populations. We will demonstrate that decreasing the levels of carcass ingestion by removal of carcasses in game reserves, for example, may not always lead to a reduction in the population of animals infected with anthrax. However, increasing levels of carcass induced environmental contamination rates in an enzootic anthrax region can result in the catastrophic extinction of a persistent animal population. (Received September 11, 2014)

1106-92-1205 **Lake Ritter***, SPSU: Department of Mathematics, 1100 S. Marietta Pkwy, Marietta, GA 30060. *A preliminary model of phosphorylation states of endothelial nitric oxide synthase.* Preliminary report.

Nitric oxide is an important cellular signaling molecule, and endothelial nitric oxide synthase (eNOS) serves as a signaling junction box receiving various inputs and regulating NO production for control in processes of homeostasis, adaptation, and development (e.g. vascular tone, insulin production, angiogenesis, etc.). Various agents influence NO production via phosphorylation and dephosphorylation of eNOS. Evidence of oscillation between inactive and active states of kinases and phosphatases has been detected experimentally consistent with feedback mechanism in signal transduction. We consider a feedback model for phosphorylation in eNOS signaling described by a coupled system of ordinary differential equations. Introduction of time delays (corresponding to formation of protein complexes, diffusion, interactions of unspecified intermediaries, etc.) is considered and is shown to produce oscillatory behavior. (Received September 11, 2014)

1106-92-1219 **Megan O Powell*** (mpowell@stfrancis.edu), University of St. Francis, 500 Wilcox, Joliet, IL 60435. *Modeling population decline of Tasmanian devils due to the spread of Devil facial tumor disease (DFTD).*

DFTD is a transmissible parasitic cancer that, since the first reported case in 1996, has caused Tasmanian devil populations to decline dramatically. Several strategies such as selective culling and isolation have been suggested by biologists to help ensure that devils will escape extinction. In this talk, I will discuss a system of ordinary differential equations used to evaluate these strategies. Additionally, I will discuss the sensitivity of the model's population predictions to various disease factors. (Received September 11, 2014)

1106-92-1244 **Abra Brisbin***, Department of Mathematics, University of Wisconsin-Eau Claire, 105 Garfield Ave, Eau Claire, WI 54702, and **Michelle Pflughoeft**, **Harrison Reeder**, **Samir Rachid**, **Aleksandra Mandic**, **Andrew Boyd** and **Guoxi Lei**. *Statistical tests for genetic associations in populations with three-way admixture.* Preliminary report.

Admixed individuals, such as many Latinos, have DNA from multiple ancestries. Identifying the ancestry of small regions of DNA can enhance statistical tests for association between genes and diseases or other traits. In this work, we compare 6 methods of incorporating ancestry into genetic association mapping for simulated binary and quantitative traits. We also compare two approaches to extend each method from two-population admixture to three-population admixture. Surprisingly, for 5 of the methods, the naïve approach of comparing each ancestry versus the other two is as powerful as modeling all three ancestries jointly. However, it is also more computationally intensive due to the need for permutation testing. (Received September 11, 2014)

1106-92-1257 **Nicole M Panza*** (nmpanza@ncsu.edu), Department of Mathematics, Box 8205, North Carolina State University, Raleigh, NC 27695-8205, and **James Selgrade** (selgrade@math.ncsu.edu), Department of Mathematics, Box 8205, North Carolina State University, Raleigh, NC 27695-8205. *Modeling Follicle Wave Dynamics in the Menstrual Cycle.* Preliminary report.

A model of nonlinear differential equations which represents the hormonal regulation of the menstrual cycle with follicle waves is presented. Such waves have been observed in animals and have been reported in women by Baerwald et al. (2003). Our model exhibits multiple waves of antral follicles during a woman's cycle using a Follicle Stimulating Hormone threshold function. Both 2-wave and 3-wave cycles are simulated and the 2-wave cycle is simulated for both the 5 and 6 hormone models. (Received September 11, 2014)

1106-92-1258 **Brian Dennis*** (brian@uidaho.edu) and **William P Kemp** (william.kemp@ars.usda.gov). *Allee effects and colony collapse disorder in honey bees.*

We propose a mathematical model to quantify the hypothesis that a major ultimate cause of Colony Collapse Disorder (CCD) in honey bees is the presence of an Allee effect in the growth dynamics of honey bee colonies. In the model, both recruitment of adult bees as well as mortality of adult bees have substantial social components, with recruitment enhanced and mortality reduced by additional adult bee numbers. The result is an Allee effect, a net per-individual rate of hive increase that increases as a function of adult bee numbers. The Allee effect creates a lower critical size in adult bee numbers below which mortality is greater than recruitment, with ensuing loss of viability of the hive. Under ordinary and favorable environmental circumstances, the critical size is low, and hives remain large, sending off viably-sized swarms (naturally or through beekeeping management) when hive numbers approach an upper stable equilibrium size. However, both the critical size and the upper stable size depend on many parameters related to demographic rates their and enhancement by bee sociality. The model suggests that multiple proximal causes, among them pesticides, mites, pathogens, and climate change, working singly or in combinations, could trigger CCD by exacerbating the Allee effect. (Received September 11, 2014)

1106-92-1264 **Courtney L Davis*** (courtney.davis2@pepperdine.edu), Pepperdine University, 24255 Pacific Coast Highway, Malibu, CA 90263-4321, and **Rezwanul Wahid**, **Frank R Toapanta**, **Marcelo B Sztein** and **Doron Levy**. *A Clinically Parameterized Mathematical Model of Shigella Immunity to Inform Vaccine Design.*

We mathematically examine what key aspects of the humoral immune response should be elicited to create an effective vaccine against the bacteria Shigella. Shigella, a member of the same family as E. coli, causes one million deaths every year. No vaccine exists for Shigella despite decades of experimental research and clinical trials, in part because the multiple immune components responsible for conferring immunity against Shigella are not known.

I will describe how we are using ordinary differential equation models to search for promising Shigella vaccine targets. We have developed an ODE model of the antibody and B-cell immune response against Shigella, and we parameterize our model using clinical trial vaccine data. We use Latin hypercube sampling and Monte Carlo parameter estimation with this clinical data to identify realistic, biologically grounded parameter value combinations. Subsequent sensitivity analysis enables us to predict which crucial parameters and parameter ranges correlate with disease prevention and clearance. The long-term goal of this collaborative research is to identify which key immune-bacterial interactions should be targeted by a vaccine to successfully protect against Shigella infection. (Received September 11, 2014)

1106-92-1268 **Marco V. Martinez*** (mvmartinez@noctrl.edu). *Optimal Control for Management in Gypsy Moth Models.*

The gypsy moth, Lymantria dispar (L.), is probably the most destructive forest defoliator in North America. Gypsy moth outbreaks tend to be spatially synchronized over areas across hundreds of kilometers. Outbreaks can result in loss of timber and other traditional forestry products. Greater losses tend to occur to the ecosystem services that forests provide, such as wildlife habitat and nutrient cycling.

The United States can be divided in three different areas: A generally infested area (where gypsy moth populations are established), an uninfested area (populations are not established), or a transition zone between the two. There are different management programs matching these different areas. This work focuses in optimal control techniques for models of areas where the population is established or in the invasion front.

We design an objective functional to minimize the cost generated by the defoliation caused by the population of gypsy moth and the cost of controlling the population with an aerial spray. The objective was to develop an optimal control framework and perform numerical simulations for various scenarios, that seeks to minimize the total cost due to gypsy moth (damage plus control cost). (Received September 11, 2014)

1106-92-1294 **Kehinde Rilwan Salau*** (krsalau@email.arizona.edu), **Jacopo A Baggio**, **Eli P Fenichel**, **Marco A Janssen** and **Joshua K Abbott**. *Taking a moment to measure networks – A hierarchical approach.*

Network-theoretic tools contribute to understanding real-world system dynamics, e.g., in epidemics, power outages, and wildlife conservation. Network visualization helps illustrate structural heterogeneity; however, details about heterogeneity are lost when summarizing networks with a single mean-style measure. Researchers have indicated that a hierarchical system composed of multiple metrics may be a more useful determinant of structure, but a formal method for grouping metrics is still lacking. We develop a hierarchy using the statistical concept of moments and systematically test the hypothesis that simple metrics are sufficient to explain the variation in processes that take place on networks, using an ecological systems example. Results indicate that the moments approach outperforms single summary metrics and accounts for a majority of the variation in process outcomes. The hierarchical measurement scheme is helpful for indicating when additional structural information is needed to describe system process outcomes. (Received September 11, 2014)

1106-92-1341 **Elsa Schaefer*** (elsa@marymount.edu), Department of Mathematics, Marymount University, 2807 North Glebe Road, Arlington, VA 22030, and **Olcay Akman**, **K. Renee Fister**, **Holly Gaff**, **Suzanne Lenhart** and **Marina Romadan**. *Approaches in parameter and model selection for the study of cholera.*

We first consider multiple model structures for cholera that are supported by a mechanistic understanding of the disease. For each possible model, we use genetic algorithms to find multiple parameter sets that describe available data sets equally well. We explore how established model comparison criteria (AIC) can be used to select the most appropriate model to support the available data, and we examine uncertainty in those recommendations and whether alternative criteria can provide additional insights. Finally, we discuss a comparison of intervention strategies provided by optimal control as an important consideration in model selection. (Received September 12, 2014)

1106-92-1387 **Julie C Blackwood***, jcb5@williams.edu. *Allee effects and invasive insect management: how to optimally allocate resources.*

Effectively controlling the establishment and spread of invasive insects is critical from both economic and ecological perspectives. In the early stages of an invasion, an invasive pest is typically found at low densities and therefore may be subject to local extinction resulting from the interplay of Allee effects and demographic stochasticity. We analyze models that consider multiple forms of pest management including pesticide application, the release of false pheromone sources, and the introduction of strains of Wolbachia that are capable of inducing cytoplasmic incompatibilities. We explore the role of these tactics in creating or enhancing pre-existing Allee effects and identify key considerations for creating an effective management plan. (Received September 12, 2014)

1106-92-1390 **Olivia F Prosper*** (olivia.f.prosper@dartmouth.edu), **Nick Ruktanonchai** and **Maia Martcheva**. *An evaluation of malaria vaccines as a control strategy in regions with naturally acquired immunity.*

Following over two decades of research, the malaria vaccine candidate RTS,S has completed the final stages of vaccine trials, demonstrating an efficacy of roughly 50% in young children. Regions with high malaria prevalence tend to have high levels of naturally acquired immunity (NAI) to severe malaria; NAI is caused by repeated exposure to infectious bites and results in large asymptomatic populations. In this talk, I will introduce the malaria model we developed to address concerns about how these vaccines will perform in regions with existing NAI, discuss some analytic results and their public health implications, and reframe our question as an optimal control problem. (Received September 12, 2014)

1106-92-1481 **Heather Smith*** (smithhc5@email.sc.edu) and **István Miklós**. *Sampling Single Cut-or-Join Scenario.*

Gene rearrangement is a common mode of molecular evolution. One basic mathematical model which prescribes a set of allowable moves for gene rearrangement is single cut-or-join. It is reasonable then to ask how the genes of one genome can be “rearranged” so that it evolves into another quickly.

To take this one step farther, fix a collection of genomes $\mathcal{G} = \{\mathcal{G}_1, \mathcal{G}_2, \ldots, \mathcal{G}_n\}$. Label the leaves of a star with the genomes in $\mathcal{G}$. The middle of the star will be labelled with a genome $\mathcal{G}_M$ which is “close” to $\mathcal{G}$. The number of rearrangements admitted by $\mathcal{G}_M$ is the product of the number of ways one can evolve $\mathcal{G}_M$ into each $\mathcal{G}_i$. Over all possible $\mathcal{G}_M$, we would like to uniformly sample from the admitted rearrangements.

Miklós, Kiss, and Tannier (2014) examined this same question, but for binary trees rather than stars. They found that no polynomial-time algorithm exists which will sample the rearrangements almost uniformly unless RP=NP. In this talk, I will present a complexity result for the analogous problem on the star. (Received September 13, 2014)

1106-92-1486 **Faina Berezovskaya***, fberezovskaya@howard.edu, and **Georgiy Karev**. *Bifurcation approach to analysis of mathematical model of CRISPR hosts/virus population.*

One of the adaptation mechanisms employed by microbes to curb viruses is the CRISPR-Cas system, a recently discovered adaptive immunity system. Microbes create heritable memory of viruses thus following the Lamarckian modality of evolution that dramatically accelerating adaptation. Population studies and modeling reveal complex behavior of the actual populations. We construct and study a “minimal”3-dimensional Volterra type analytical model of the CRISPR-Cas system (Berezovskaya et.al., Biology Direct 2014, 9:13).

Theorem. Let M be the virus reproduction rate; then for a wide range of other model parameters and any positive initial values the stable mode of the model is the equilibrium for ”M¡M_cr” and stable (pseudo-chaotic) oscillations for ”M¿M_cr”, where ”M_cr” is the parameter value corresponding to supercritical Hopf bifurcation.

Quasi-chaotic regimes of virus-host coevolution are likely to be biologically relevant given the extreme evolutionary instability of the CRISPR-Cas loci revealed by comparative genomics. (Received September 13, 2014)

1106-92-1555 **John G Alford*** (jalford@shsu.edu), Lee Drain Building, Room 420, 1900 Avenue I, Huntsville, TX 77340, and **William I Lutterschmidt**. *Costs and Benefits of Lizard Thermoregulation Revisited: From Conceptual to Computational Models.*

Behavioral thermoregulation in ectothermic vertebrates has been an area of major theoretical interest and has inspired a diversity of discussions among scholars of ecology, physiology and evolutionary biology. This research has generated many interesting mathematical problems. In this talk we discuss the mathematics of a conceptual model posed by Huey and Slatkin (1976) that is used to determine the thermoregulatory strategy that maximizes the energetic gain of a lizard. The model equations account for the cost and benefit of thermoregulation and thermal quality of habitat. Huey and Slatkin's conceptual model has served as a seminal work advancing energetic considerations of behavioral thermoregulation and established a theoretical foundation in thermal biology, but has not (to our knowledge) been investigated with a detailed quantitative analysis. We create mathematical formulas that mimic Huey and Slatkin's graphical depictions of the functions in their model equations and use numerical methods to analyze the model. Not only do our results illustrate both the utility and mathematical validity of Huey and Slatkin's qualitative analysis, but they also provide new insight into the theory of behavioral thermoregulation. (Received September 14, 2014)

1106-92-1620 **Rachel Leander*** (rachel.leander@mtsu.edu), Murfreesboro, TN, and **Edward Allen**, **Darren Tyson**, **Shawn Garbett**, **Zach Jones** and **Vito Quaranta**. *Modeling the dynamics of intermitotic time distributions.* Preliminary report.

Empirical distributions of intermitotic times (IMTs) show the time it takes a cell to divide is highly variable; the final response to drug treatment is not uniform; and it takes multiple cell cycles for an IMT distribution to stabilize post perturbation. In this talk, I will present a stochastic model of the cell cycle and discuss the model's validity and biological implications. (Received September 14, 2014)

1106-92-1649 **Yu Jin*** (yjin6@unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588, and **Jon Jacobsen** and **Mark A. Lewis**. *Population persistence in temporally varying river environments.*

We study integrodifference models for growth and dispersal in the presence of advective flow with both periodic (alternating) and random kernel parameters. For the alternating kernel model, we obtain the principal eigenvalue of the linearization operator to determine population persistence and derive a boundary value problem to calculate it. For the random model, we establish two persistence metrics: a generalized spectral radius and the asymptotic growth rate, which are mathematically equivalent but can be understood differently, to determine population persistence or extinction. The theoretical framework and methods for calculations are provided, and the framework is applied to calculating persistence in highly variable river environments. (Received September 14, 2014)

1106-92-1661 **Abba Gumel*** (agumel@asu.edu), ECA 347, Tempe, AZ, and **Folashade Agusto** and **Paul Parham**. *Mathematical Assessment of the Role of Temperature Variations on Malaria Transmission Dynamics.*

Climate drivers, such as temperature, rainfall, vapor pressure, humidity etc., are known to influence the incidence of vector-borne diseases. This talk focusses on the use of mathematical modeling and analysis to assess the impact of variations in temperature on the transmission dynamics of malaria, the most prevalent human vector-borne disease. Relevant data (temperature, epidemiological, ecological and demographic) from some malaria-endemic regions will be used to parametrize the resulting non-autonomous deterministic system of non-linear differential equations. It is shown that malaria incidence increases for increasing temperature until a certain temperature threshold is reached, above which the incidence declines. (Received September 14, 2014)

1106-92-1695 **Kurt E. Anderson**, **Scott Manifold** and **Jonathan Sarhad*** (jonathan.sarhad@gmail.com). *Population persistence in stochastic river networks.* Preliminary report.

Freshwater scientists are increasingly demonstrating that the branching structure of river networks has substantial ecological consequences. We study population persistence using a reaction-diffusion-advection equation on a metric graph which provides a continuous, spatially explicit model of the river network habitat. Within this framework, we stochastically generate hypothetical river networks with a variety of geometric features and explore the effects of network structure and the distribution of habitat within the network on the persistence of a hypothetical, highly mobile population. We identify an index, CM, related to the distribution of habitable volume in the network as a promising indicator of population persistence potential. The index CM is the distance from the river outflow point at which half of the habitable volume of the river network lies upstream of that distance. This index outperforms other metrics such as the maximum and minimum distance from the river outflow to an upstream boundary and the total habitable volume of the network. In doing so, it provides a better generalization of habitat length in the classical linear space models of a river segment than these other metrics, when considered in the context of persistence in river networks. (Received September 15, 2014)

1106-92-1706 **Kathryn R Hedrick*** (khedrick@jhu.edu). *Megamap: Flexible representation of a large space by a hippocampal continuous attractor network.*

The brain stores a cognitive map of a spatial region through the activity of specialized cells called place cells. According to the traditional theory, each place cell fires within a single subregion, known as the cell's place field, and the network of place cells forms a continuous attractor by modifying the strength of connections among cells. We extend this theory by proposing that the hippocampus stores a megamap, or a continuous attractor representing a large region, in which each cell may have multiple, irregularly spaced place fields. We first show that the system can stably represent a large region by setting the connections optimally such that the expected attractor states are fixed points of the dynamical system governing cellular activity. Through numerical simulations and perturbation analysis, we examine the computational properties that emerge as the represented region becomes sufficiently large. We demonstrate that the system transitions to a combinatorial mode in which spurious attractor states reflect environmental changes by combining previously stored memories. Consequently, the megamap extends the size of the region a place cell network can represent while uniting stability and flexibility as two fundamental properties of hippocampal networks. (Received September 15, 2014)

1106-92-1772 **Barrett J. Anderies*** (banderie@asu.edu), 9632 S. 45th Place, Phoenix, AZ 85044, and **Eric J. Kostelich**.

Computational Modeling of Murine GL261 Brain Tumors .

We consider stochastic parameterizations of a diffusion–logistic growth model suggested by Swanson and Murray:

$$\frac{\partial u}{\partial t} = \nabla \cdot (D\nabla u) + \alpha u(p-u)$$

An Ornstein-Uhlenbeck process was used to generate stochastic values for D and α. Ensemble simulations were run with varying stochastic parameters and initial conditions. The results of each ensemble were used to generate an average tumor for the set of parameters and initial conditions.

These simulations were compared to T2 weighted MRI data from a Murine in vivo brain tumor experiment. Immunocompetent mice had GL261 tumor cells injected into their brain tissue, and the progression of tumor growth was monitored for a twenty-five day period. Our simulation tumor volumes were within $0.5\,\mathrm{mm}^3$ of observed volumes, and tumor cell distribution matched closely with observed T2 weighted MRI data. (Received September 15, 2014)

1106-92-1774 **Katherine Morrison*** (katherine.morrison@unco.edu), University of Northern Colorado, Ross Hall 2239/ CB 122, 501 20th St, Greeley, CO 80639. *Properties of Neural Codes via the Neural Ring.*

The brain represents stimuli via patterns of neural activity. These activity patterns can be described by a neural code, i.e. a collection of indicator vectors showing which neurons co-fire in response to various stimuli. Neuroscientists seek to understand how the brain determines properties of the underlying stimulus space without access to the encoding map. It is believed that the brain can infer many properties of the stimulus space purely from the intrinsic structure of the neural code. We focus on convex receptive field codes, which have encoding maps that have been observed experimentally. In these codes, each neuron corresponds to a convex region of the stimulus space and the neuron fires when the stimulus falls within that region. Based solely on the intrinsic structure of the neural code, we wish to understand whether the code is a convex receptive field code and if so, to determine the minimal dimension of the underlying stimulus space that gave rise to the code. In this talk, we will show how the neural ring, an algebraic object that captures the full combinatorial data of the code, can be used to address these questions. This is joint work with several authors from an AMS Mathematics Research Community. (Received September 15, 2014)

1106-92-1782 **Timothy D Comar*** (tcomar@ben.edu), Department of Mathematics, Benedictine University, 5700 College RD, Lisle, IL 60532, and **Olcay Akman** (oakman@ilstu.edu) and **Daniel Hrozencik** (dhro@att.net). *Model Selection for Integrated Pest Management with Stochasticity.*

We extend existing impulsive differential equation models for integrated pest management (IPM) by including stage structure for both predator and prey as well as by adding stochastic elements in the birth rate of the prey. Based on our model, we propose an approach that incorporates various competing stochastic components. This approach enables us to select a model with optimally determined weights for maximum accuracy and precision in parameter estimation. This is significant in the case of integrated pest management because the proposed model accommodates varying unknown environmental and climatic conditions, which affect the resources needed for pest eradication. (Received September 15, 2014)

1106-92-1811 **R. R. Slechta*** (ryan@stthomas.edu). *Reassembling Humpty Dumpty: 3D Puzzles and Invariant Signature Curves.*

The end goal of this research is to virtually reconstruct a broken ostrich egg by devising an algorithm to automatically solve 3D jigsaw puzzles. In order to determine which egg pieces fit together, we look to use "snake" techniques to extract invariant signature curves and easily compare the egg piece boundaries. A method currently exists to assemble 2D puzzles, and we address the complications associated with extending it to 3D. In addition, we attempt to develop an efficient method to randomly generate 3D puzzles with no severe restrictions on shape or arrangement, enabling us to easily test the efficiency of the reassembly method. (Received September 15, 2014)

1106-92-1814 **John M Calhoun*** (john.m.calhoun@ttu.edu). *large scale multi agent simulation of infectious disease on the lazarus gpu cluster with applications to epidemiology and zombies.*

the lazarus project provides a gpu computing cluster to run and analyze multi-agent simulations. infectious diseases such as malaria or a zombie like virus can be simulated and data can be collected at a more intense level than would be possible in the real world. this data can then be studied in a number of different ways to gain insight in to how these diseases spread and predict their macro-system behavior from micro and individual characteristics. in particular, machine learning and neural networks can be used to understand the data. all of these tasks from simulation to analysis involve many computationally intensive tasks and leveraging powerful computers such as the gpu cluster at texas tech can allow these techniques to be fully utilized. the many challenges, solutions, and results from this project will be discussed. (Received September 15, 2014)

1106-92-1840 **Gangaram S Ladde*** (gladde@usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, Tampa, FL 33620-5700. *A THRESHOLD NETWORK DYNAMIC AND APPLICATIONS.* Preliminary report.

In this work, we focus on the threshold dynamic networks. By developing discrete iterative inequalities, energr/Lyapunov function approach, comparison results for discrete iterative process under environmental and Markovian perturbation are presented. By using the comparison results, the qualitative properties of both stochastic and deterministic automata networks are analyzed. Several applications are given to illustrates the usefulness of the results. (Received September 15, 2014)

1106-92-1841 **Rebecca A Everett*** (rarodger@asu.edu), P.O. Box 871804, Tempe, AZ 85287-1804, and **Yang Kuang** (kuang@asu.edu), P.O. Box 871804, Tempe, AZ 85287-1804. *Applications of the Droop Cell Quota Model to Cancer Treatment.*

The phycologist Droop studied vitamin B_{12} limitation in the flagellate *Monochrysis lutheri* in chemostats and concluded that the specific growth rate did not depend directly on the medium substrate concentration, but rather depended on the concentration of the vitamin within the cell, or the cell quota. The Droop equation has been used often in mathematical ecology models, such as in ecological stoichiometry. Since cancer cells live in an ecological setting, we apply the idea of a limiting nutrient to cancer modeling, using the Droop equation to model cancers, including prostate cancer and ovarian cancer. (Received September 15, 2014)

1106-92-1842 **Patricia K McCarthy*** (patricia.mccarthy@loras.edu) and **Jeremy Burke**. *Cancer Stem Cells in treating Glioblastoma Multiform Brain Cancer.*

In this talk, we present an extension of the work of Kogan, Forys, and Kronik (Kogan, et al. 2008). Our work incorporates the cancer stem cell hypothesis in the study of treatment of Glioblastoma Multiforme by immunotherapy. We propose an abstract model of nonlinear ordinary differential equations and show existence of coexistence, recurrence, and cure steady states. We perform stability analysis and present sufficiency conditions on treatment parameters to ensure a globally asymptotically stable cure state. We then present a biologically accurate example of the model that showcases the abstract theory. We conclude with numerical simulations that utilize the Dirac delta function to realistically model administration of the immunotherapy treatment. (Received September 15, 2014)

1106-92-1843 **Kamuela E Yong*** (kamuela.yong@asu.edu), PO Box 873901, Tempe, AZ 85287-3901. *Necessary and sufficient conditions for instability in an SI model.* Preliminary report.

In a spatial epidemiological model, it is important to study the movements of populations and determine if patches of susceptible and infective individuals exist. In this study we examine a spatial SI model with cross-diffusion and determine the necessary and sufficient conditions for Turing instability. Numerical simulations are provided to verify the results. (Received September 15, 2014)

1106-92-1846 **Ruth Davidson*** (redavid2@illinois.edu), **Siavash Mirarab** (smirarab@cs.utexas.edu) and **Tandy Warnow** (warnow@illinois.edu). *Using Phylogenetic Invariants in Coalescent-Based Methods.* Preliminary report.

A phylogenetic tree represents the common evolutionary history of a collection of genes or species. Phylogenetic invariants are polynomial relationships in probabilities associated to models of evolutionary processes. Thus an invariant can give an algebraic encoding of a tree shape representing a specific evolutionary history. Phylogenetic invariants were first introduced in the biology community in 1987. Their study has led to many beautiful results in algebraic geometry and provided interesting links between this classical field of mathematics and discrete optimization problems. In practice, a biologist may consume a combination of techniques when making trees, and methods for large datasets-those which include large numbers of species and/or large numbers of data samples from various loci in the genome from each species-often combine distinct methods for sub-problems into a pipeline. We investigate the problem of exploiting theoretical results about phylogenetic invariants to improve existing pipelines for tree estimation and propose new approaches, with an emphasis on coalescent-based methods. We give some new confidence bounds for the use of invariants in coalescent-based methods that correspond to properties of real data sets. (Received September 15, 2014)

1106-92-1860 **Kelsey Pearson**, 2115 Summit Ave, St Paul, MN 55105, and **Naomi Latt*** (latt6047@stthomas.edu), 2115 Summit Ave, St Paul, MN 55105. *Applications of Mathematical Modeling in Diagnosing Breast Cancer.*

Mammography persists as a challenge in radiology because the structural differences between benign and malignant tumors are indistinguishable to the human eye. However, the application of fractal dimensions and cumulative distance histograms can diagnose breast tumors by mathematically analyzing contours. Our methodology extends to using fractal dimensions, which are a numerical measure of the complexity and irregularity of an object. Using the box counting method to calculate the fractal dimension, tumors can be diagnosed as cancerous or benign. A higher fractal dimension corresponds to a more complex and irregular contour, indicating a cancerous tumor; in contrast, a lower fractal dimension indicates a benign tumor. The final method we use is invariant distance histograms, which are formed by collecting a sample of distances between random points on the contour. Benign and malignant invariant distance histograms are compiled to create two respective cumulative distance histograms. The curve of best fit for these histograms can be compared for diagnosis because the curves of benign tumors differ from those of malignant tumors. (Received September 15, 2014)

1106-92-1866 **Chrono Strai Nu*** (csn1009@westminstercollege.edu) and **Richard Wellman**. *An exploratory investigation using electroencephalography and machine learning techniques for fine motor classification in the EggLink brain-computer interface.* Preliminary report.

The EggLink is an electroencephalography-based brain-computer interface that will operate common household computers based on numerous data transformation techniques and machine learning classifications of fine motor signals generated in the brain. At this stage, the project involves exploring how subtle differences in measurable neurological signals can be revealed mathematically for the prototype system that classifies fine motor activity (the flicking of each of 10 fingers) to a high degree of accuracy. The performance of the system will be discussed in terms of overall accuracy of true positive predictions made by machine learning ensembles. (Received September 15, 2014)

1106-92-1907 **Heather Gronewald*** (gronewah@southwestern.edu). *Computing Cophylogenetic Invariants.*

Phylogenetics is the study of evolutionary relationships among organisms. One method for reconstructing phylogenetic trees involves establishing phylogenetic invariants (polynomial relationships that vanish when expected pattern frequencies are substituted for variables) and then comparing expected and observed invariants. Cophylogeny is the study of concomitantly evolving organisms (e.g. a host and parasite). Huggins, Owen, and Yoshida suggest that existing methods for reconstructing host and parasite trees can exaggerate true differences between trees. We consider both the independent and pairwise reconstruction of trees, establishing classes of metrics for which independently inferred trees match pairwise inferred trees, and exploring methods for reconstruction that consider the cophylogenetic relationship. (Received September 15, 2014)

1106-92-1908 **Peter A Muller*** (muller@math.colostate.edu), **David Isaacson**, **Gary Saulnier** and **Jonathan Newell**. *A finite difference approach to solving the D-bar equation.*

This talk is motivated by the inverse boundary value problem of electrical impedance tomography (EIT). The D-bar equation arises when using complex geometrical optics to solve the full non-linear EIT problem. This partial differential equation is traditionally solved numerically with integral equation solvers. We seek to solve the D-bar equation in its original form via finite differences. This results in solving a system of first order PDEs. Here we develop second-order schemes for solving a general class of D-bar problems. These schemes are then applied to image reconstruction algorithms, which motivated their development. (Received September 15, 2014)

1106-92-1917 **Ryan M Thurman***, Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, Tampa, FL 33620-5700, and **Gangaram S Ladde** (gladde@usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, Tampa, FL 33620-5700. *Epidemiological Modeling and Stochastic Neural Networks.* Preliminary report.

The human will to preserve life makes models of infectious disease spread invaluable to society; for such models assist in disease prevention—the continuation of life. Artificial Neural Networks offer a means by which complex dynamic stochastic systems can be modeled using network structures. This paper involves the use of stochastic neural networks to model epidemiological processes that involve internal, external, and hereditary influences. The current model is an extension of the Markov network that has been used to model infectious diseases—under simpler conditions—in the past. (Received September 15, 2014)

1106-92-1918 **Glenn Ledder*** (gledder@unl.edu). *An Optimization Model that Links Masting to Seed Herbivory.*

Masting is a life history strategy whereby perennial plants have one or more years of little or no reproduction, punctuated by years with massive reproduction events. The literature on masting focuses on description of this behavior, particularly the common observation that individuals in a population act in synchrony. To date, there is no published work that connects masting to characteristics of the ecological niche of the plant species, such as the overall growing capacity or the extent of seed herbivory. In this study, we develop a resource-based optimization model with seed herbivory risk as a key parameter, and we use dynamic programming to show that the optimal strategy for such a scenario can be periodic masting, with the masting interval an increasing function of seed herbivory risk. (Received September 15, 2014)

1106-92-1973 **Anna Grim*** (grim4684@stthomas.edu), 2115 Summit Avenue, St. Paul, MN 55105. *Diagnosing Breast Cancer with Symmetry of Signature Curves.*

Mammography persists as a challenge in radiology because the structural differences between benign and malignant tumors are indistinguishable to the human eye. However, the unprecedented application in symmetry of signature curves can diagnose breast tumors by mathematically analyzing curvature. Our methodology quantifies a 2-dimensional (2D) tumor contour C by the rigidly invariant curvature parametrization $C = \{\kappa(t), \kappa'(t)\}$, where $\kappa(t)$ is curvature and $\kappa'(t)$ is the derivative of curvature. The malignancy of a tumor is determined by the frequency, range, and density of zero curvature points, where either $\kappa(t) = 0$ or $\kappa'(t) = 0$. In addition, contrasting global versus local symmetry patterns in the signature curve further distinguish malignancy. Benign tumors are distinctive by a high degree of global symmetry calculated from the 2D tumor contour. Whereas, malignant tumors exhibit multiple types of local symmetry embedded within their signature curve. The methodology has been implemented on over 150 tumors, demonstrating a strong correlation between curvature complexity and symmetry patterns with malignancy.
(Received September 15, 2014)

1106-92-1984 **Xiang-Sheng Wang*** (xswang@semo.edu), Department of Mathematics, Southeast Missouri State University, Cape Girardeau, MO 63701, and **Jianhong Wu**. *Periodic systems of delay differential equations and the dynamics of avian influenza.*

Modelling the spread of avian influenza by migratory birds between the winter refuge ground and the summer breeding site gives rise to a periodic system of delay differential equations exhibiting both the cooperative dynamics (transition between patches) and predator-prey interaction (disease transmission within a patch). Such a system has two important basic reproductive ratios, each of which being the spectral radius of a monodromy operator associated with the linearized sub-system (at a certain trivial equilibrium): the (ecological) reproduction ratio for the birds to survive in the competition of birth and natural death, and the (epidemiological) reproduction ratio for the disease to persistent. We calculate these two ratios by our recently developed finite dimensional reduction and asymptotic techniques, and we show how these two ratios characterize the nonlinear dynamics of the full system. (Received September 15, 2014)

1106-92-1988 **Richard L Rebarber*** (rebarber@unl.edu), **Chris Guiver** (c.guiver@ex.ac.uk), **Stuart Townley** (s.b.townley@ex.ac.uk), **Hartmut Logemann** (mashl@bath.ac.uk), **David Hodgson** (d.j.hodgson@ex.ac.uk), **Adam Bill** (a.r.bill@bath.ac.uk) and **Brigitte Tenhumberg** (btenhumberg2@unl.edu). *Feedback control methods for population management.*

We present two novel feedback control methods for population management. We assume that only partial measurements of the population are available for use in these management strategies, and refer to these measurements as observations. For instance, the observation of a stage-structured population might be just the population in a reproductive stage. The first strategy uses integral control, which is a dynamic feedback of the observation which is used to regulate the whole population to a desirable constant population. The second strategy involves the notion of an observer, a dynamical process for estimating the whole population based solely on the observation; in this case the estimated state can be used in a feedback instead of just the observation. Integral control and observers are ubiquitous in control engineering, but have not received much attention in ecological modeling. This type of control is robust to model uncertainty and external disturbances, important considerations for ecological models. We illustrate these control strategies with population management examples. (Received September 15, 2014)

1106-92-2015 **Margaret M McDaniel*** (mmcdan15@vols.utk.edu), **winode g Handagama**, **Nitin Krishna**, **shigetoshi Eda** and **Vitaly Ganusov**. *A Quantitative and Mechanistic Approach to Model Replication,Death and Quiescence of Mycobacterium tuberculosis in Mice.* Preliminary report.

According to the World Health Organization, an estimated 2.3 billion people are infected with *Mycobacterium tuberculosis* (Mtb). Despite decades of research, the physiology of tuberculosis remains poorly understood. Current models for Mtb hold that the total bacterial burden approaches a static equilibrium during chronic infection. A recent study of Mtb-infected mice by Gil et al. used a mathematical model to show that bacterial replication and death rates do not necessarily remain constant. In our study, we extend this model by investigating the effects of a time-dependent segregation rate and the inclusion of quiescence to find limits on growth rates that are consistent with bacteria counts. We find that there are alternative hypotheses to tuberculosis pathogenesis that lead to lower predictions of Mtb replication and death rates. We also show that replication and death rates of Mtb may be higher than initially predicted when bacterial quiescence is added into the model. A mechanistic model was then constructed to account for the population of macrophages, bacteria, and the host immune response. We find that a time-dependent rate of necrosis was necessary to explain the same experimental data. (Received September 15, 2014)

1106-92-2024 **Christopher J Hillar*** (chillar@berkeley.edu), Redwood Center for Theoretical Neuroscience, University of California, Berkeley, 575A Evans Hall, MC 3198, Berkeley, CA 94720. *Biologically inspired real-world applications of discrete mathematics.*

We explain how the problem of sensory coding in theoretical neuroscience led us to the discovery of remarkable properties of maximum entropy distributions on graphs and Hopfield binary recurrent neural networks. Importantly, the algebra, geometry, and combinatorics of such objects plays a major role. (Received September 15, 2014)

1106-92-2043 **Kang-Ling Liao*** (liao.92@osu.edu), 376 Jennings Hall, 1735 Neil Ave., Columbus, OH 43202, and **Avner Friedman** and **Xue-Feng Bai**. *The contradictory experimental results of CD200-CD200R in cancer proliferation.*

CD200 is a cell membrane protein that interacts with CD200 receptor (CD200R) of myeloid lineage cells. During tumor initiation and progression, CD200-positive tumor cells can interact with M1 and M2 macrophages through CD200-CD200R-compex to silence macrophages. However, the functions of M1 and M2 cells in tumor growth are different, so CD200-CD200R has been shown to have apparently two contradictory experimental results in tumor growth: inhibition in melanoma and promotion in papilloma. We used a system approach to determine the combined effect of CD200-CD200R interaction on tumor proliferation by developing a mathematical model. We explained why these two opposite experimental results can both take place depending on the "affinity" of

M1 and M2 macrophages to form the complex CD200-CD200R with tumor cells. If M1 cell has more affinity than M2 cell, then CD200-CD200R promotes tumor growth and block CD200-CD200R could be a good therapy. However, if M2 cell has more affinity than M1 cell, then we have opposite result that block CD200-CD200R will only increase tumor growth. Our results help understanding the complexities of tumor microenvironment. (Received September 15, 2014)

1106-92-2047 **Stanley L. Tuznik*** (slt5237@psu.edu). *The Neurodynamics of Bursting Oscillations in the Hindmarsh-Rose Model.* Preliminary report.

The Hindmarsh-Rose model is a popular choice for simulating the behavior of a single neuron, as it is able to capture, qualitatively, the spiking and bursting behaviors that are observed experimentally. This three-dimensional nonlinear system relies on a slow adaptation variable which dynamically switches the neuron from a period of firing to a quiescent period, a phenomenon known as bursting. We describe the underlying mechanism behind the bursting by reducing the model to a single-parameter system in the phase plane. We then consider a simplified version of coupled oscillators used to model the coupling of two such neurons. (Received September 15, 2014)

1106-92-2063 **Daniel S. Munther*** (d.munther@csuohio.edu), **Jianhong Wu**, **Sanyi Tang**, **Yanni Xiao** and **Helio Shimozako**. *Modeling cross-contamination during poultry processing: dynamics in the chiller tank.* Preliminary report.

Understanding mechanisms of cross-contamination during poultry processing is vital for effective pathogen control. As an initial step toward this goal, we develop a dynamic model of the chilling process in a typical high speed Canadian processing plant. An important attribute of our model is that it provides quantifiable links between processing control parameters and pathogen levels, simplifying the complexity of these relationships for implementation into risk assessment models. We apply our model to *Escherichia coli* contamination on broiler carcasses, connecting pathogen control with chlorine sanitization, organic load in the water, and pre-chiller E. coli levels on the poultry. (Received September 15, 2014)

1106-92-2072 **Andrew T Sornborger*** (ats@math.ucdavis.edu) and **Louis Tao**. *Re-entrant neural circuits for actively controlled operator splitting.*

We have shown that pulse-gated synfire chains can exactly (in the mean) propagate information in the form of graded current amplitudes. Furthermore, with appropriate pulse sequences, current amplitudes may be dynamically routed through neural subcircuits. A considerable literature shows that coherent pulse trains in neural circuits can improve feature recognition, mediate interactions between neurons and modulate learning and memory. We have proposed that pulse-gated synfire chains are the theoretical mechanism responsible for this observed coherent activity. In a framework based on our pulse-gating mechanism, we have described methods for constructing neural circuits capable of actively controlling sequences of linear maps. In this paper, we demonstrate a neural circuit that combines split operator methods with re-entrant synaptic connectivity and pulse-gated control to create arbitrary rotations of vector coordinates on the sphere. (Received September 15, 2014)

1106-92-2178 **James Greene*** (jmgreene@math.umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742. *The Cell-Cycle and Drug Resistance: A Spatial Mechanism.*

Resistance to chemotherapy is a major cause of the failure cancer treatment. Our current understanding of drug resistance is that tumor heterogeneity and complex genetic and epigenetic changes contribute to the development of multi-drug resistance. Tumor heterogeneity accounts both for genetic variation, as well as non-constant tumor microenvironments. Indeed, experimental evidence suggests that different spatial configurations of cells affect drug sensitivity in a genetically homogenous population. The work presented here is focused on understanding this phenomenon.

As chemotherapeutic agents primarily target proliferating cells, spatial resistance is mediated by the variation of observed cell-cycle lengths. We first propose a continuous time Markov chain model utilizing intrinsic distributions governing the time spent in the cell-cycle. We use probabilistic techniques to derive a system of integro-differential equations, which when compared with experimental data provided by collaborators at the NIH, permit the use of optimization techniques to calculate parameter values. Furthermore, recent work uses individual-based models with explicit spatial dependencies to produce the observed cell-cycle distributions, as well as the variation in treatment efficacy based on geometry. (Received September 16, 2014)

1106-92-2234 **Felicia Maria G Magpantay*** (felicigm@umich.edu), Ann Arbor, MI 48104. *Fitting models of imperfect vaccines to pertussis incidence data.*

The resurgence of pertussis in some countries with high vaccine coverage (e.g. Canada, USA, UK) has highlighted how much we still do not know about the dynamics of this disease, particularly the type of immunity rendered by infection and vaccination. There has been much discussion on the different modes by which vaccines might fail. When a vaccine reduces the probability of infection upon exposure but does not eliminate it, this is called failure in *degree*. When the protection conferred wanes over time, this is termed failure in *duration*. Vaccines may also protect against disease but not infection and transmission. Towards the goal of determining the key features of the pertussis vaccine, we fitted an assortment of imperfect vaccine models to pertussis incidence data. Trajectory matching and Maximization via iterated Filtering (MIF) was used to obtain the maximum likelihood estimates of the model parameters using different observation models. The idea behind these algorithms and the results of its application to pertussis data will be presented. (Received September 16, 2014)

1106-92-2256 **Gunog Seo*** (gseo@colgate.edu), Department of Mathematics, Colgate University, 13 Oak Dr, Hamilton, NY 13346, and **Gail S.K. Wolkowicz** (wolkowic@mcmaster.ca). *Sensitivity of the dynamics of the general Rosenzweig-MacArthur model to the mathematical form of the functional response: a bifurcation theory approach.*

The equations in the Rosenzweig-MacArthur (RM) predator-prey model have been shown to be sensitive to the mathematical form used to model the predator response function even if the forms used have the same basic shape: zero at zero, monotone increasing, concave down, and saturating. Here, to explain this sensitivity, we revisit the RM model with three functional responses, Holling type II, Ivlev, and Trigonometric response functions, that are phenomenologically similar. We consider both the local and global dynamics and determine the possible bifurcations with respect to variation of the carrying capacity of the prey, a measure of the enrichment of the environment. We give an analytic expression that determines the criticality of the Andronov-Hopf bifurcation, and prove that although all three forms can give rise to supercritical Andronov-Hopf bifurcations, only the trigonometric form can also give rise to subcritical Andronov-Hopf bifurcation and has a saddle node bifurcation of periodic orbits giving rise to two coexisitng limit cycles, providing a counterexample to a conjecture of Kooij and Zegeling. (Received September 16, 2014)

1106-92-2262 **Elif Demirci*** (edemirci@ankara.edu.tr), Ankara University Faculty of Sciences, Department of Mathematics, Besevler, Ankara, 06100 Ankara, Turkey. *A Mathematical Model For Obesity Epidemic in a Non-Constant Population.*

In this paper, we give an epidemic model for obesity contagion. The population size is assumed to be nonconstant which is more realistic. The model considers vertical transmission of obesity and also obesity related death rate. We give local stability analysis of the model. Finally, some numerical examples are presented. (Received September 16, 2014)

1106-92-2274 **Candice R Price*** (candice.price@usma.edu). *Using Rational Knots and Links to Model Difference Topology Experiments.* Preliminary report.

Difference topology is a technique used to study a protein that can stably bind to DNA. This technique is used to determine the confirmation of the DNA bound by the protein. In this talk, I utilize a skein relation of rational knots and links to model the action of proteins used in these difference topology experiments. (Received September 16, 2014)

1106-92-2321 **Naveen K. Vaidya*** (vaidyan@umkc.edu). *Effects of drugs of abuse on HIV-1 dynamics: a mathematical model.*

Complications of HIV-1 infection with simultaneous drugs of abuse are an emergent problem. In this talk I will present a novel within-host viral dynamics model that incorporates effects of drugs of abuse on HIV-1 infection. Our model agrees well with experimental data from Simian Immunodeficiency Virus infections in morphine-addicted macaques (animal model of HIV). I will discuss how dynamical system approaches of our model help evaluate morphine-induced alterations in viral dynamics, steady state viral load, target cell population switch, and basic reproduction number. (Received September 16, 2014)

1106-92-2403 **Sara A Reynolds*** (s-sreynol5@math.unl.edu). *Pre-Copulatory Sexual Cannibalism: effects of voracity, growth, and maturation time.* Preliminary report.

The existence of high levels of pre-copulatory sexual cannibalism in some female fishing spider species is particularly perplexing, as it poses no benefit to the male and leaves the female at risk of remaining unmated. One proposed explanation for this behavior is the aggressive spillover hypothesis, where a female's propensity to cannibalize a mate is linked to her aggression towards prey. Higher levels of aggression lead to higher food consumption rates, larger adult size, and lower mating rates, a trade-off in fitness. We compare a model of the aggressive spillover hypothesis with another model that includes effects of food consumption on maturation time. We find optimal aggression levels and evolutionary stable strategies for each model, allowing a comparison of the effects of growth and maturation time on the frequency of pre-copulatory sexual cannibalism. (Received September 16, 2014)

1106-92-2407 **Scott W Greenhalgh*** (scott.greenhalgh@yale.edu), 135 College Street, Suite 200, New Haven, CT 06520, and **Jan Medlock** and **Alison Galvani**. *The dynamic modeling of disease extinction and immigration.*

Traditional differential equation models of disease transmission are often used to predict disease trajectories and evaluate the effectiveness of alternative intervention strategies. However, such models cannot account explicitly for probabilistic events, such as those that dominate dynamics when incidence numbers are low. Here we develop a novel approach, using the theory of control systems, to account for probabilistic processes, including extinction and immigration of infection, without the added analytical and computational complexity of a stochastic model. We apply our approach to analyze measles outbreaks from 1923 to 1938 in Iceland, providing insight on the temporary extinction of measles, the risk of re-emergence, and whether undocumented measles cases occurred. (Received September 16, 2014)

1106-92-2428 **Erin Boggess*** (erin.boggess@my.simpson.edu) and **Kyle Jensen** (kyle.jensen@my.simpson.edu). *DNA Hairpin Simulation using the Peyrard-Bishop Model.*

Nanotechnology has opened the door to new and innovative drug delivery methods. One promising route is releasing drugs by selectively opening a capsule latched with a DNA hairpin. We model the dynamics of the DNA hairpin as a bistable system, and predict a melting curve that can be used to manipulate the hairpin between open and closed states. We use numerical simulations to characterize the dynamics of the hairpin molecule in preparation of its future incorporation into a DNA tetrahedron prototype drug delivery capsule. (Received September 16, 2014)

1106-92-2452 **Wufeng Tian*** (wtian@broward.edu), Broward College, Judson A. Samuels South Campus, Department of Mathematics, Pembroke Pines, FL 33024, and **Shan Zhao**. *A fast ADI algorithm for nonlinear Poisson equation in heterogeneous dielectric media.* Preliminary report.

Recently, a nonlinear Poisson equation has been introduced to model nonlinear and nonlocal hyperpolarization effects in electrostatic solute-solvent interaction for biomolecular solvation analysis. Due to a strong nonlinearity associated with the heterogeneous dielectric media, this Poisson model is difficult to solve numerically, particularly for large protein systems. A new pseudo-transient continuation approach is proposed in this paper to efficiently and stably solve the nonlinear Poisson equation. A Douglas type alternating direction implicit (ADI) method is developed for solving the pseudo-time dependent Poisson equation. Different approximations to the dielectric profile in heterogeneous media are considered in the standard finite difference discretization. The proposed ADI scheme is validated by considering benchmark examples with exact solutions and by solvation analysis of real biomolecules with various sizes. Numerical results are in good agreement with the theoretical prediction, experimental measurements, and those obtained from the boundary value problem approach. Since the time stability of the proposed ADI scheme can be maintained even using very large time increments, it is efficient for electrostatic analysis involving hyperpolarization effects. (Received September 16, 2014)

1106-92-2455 **Robert J Rovetti*** (rrovetti@lmu.edu), Loyola Marymount University, Los Angeles, CA. *Simulations of a lattice model and pairwise approximation equations to predict unstable calcium release in a cardiac cell.*

The calcium release system within a single cardiac cell can be efficiently represented by a discrete-time, probabilistic lattice model with nearest-neighbor interactions. Regions within parameter space where the ensemble activity of a 10,000-node simulated lattice exhibits unstable quasi-periodic behavior (the "alternans window") correspond to physiological conditions in the cell that could lead to arrhythmia and sudden cardiac death. In simulations we explore the effect of varying geometries and spatial couplings within the lattice upon the emergence of this window. We also examine the use of the pairwise approximation (PA) method to analytically estimate the location of the alternans window by predicting the probability that a local neighborhood of n nodes will be in a particular state of activation at a particular time. The PA method requires the simultaneous solution of 2^n coupled different equations; we discuss methods for reducing the computational complexity as n increases. (Received September 16, 2014)

1106-92-2456 **Elizabeth Drellich** (drellich@math.umass.edu), **Sarah Karrpbadia**, **Sydney Ness** and **Pamela Badian-Pessot*** (pbadianpessot@smith.edu). *Modeling RNA.*

We investigate models of RNA folding and the types of secondary structures they predict. (Received September 16, 2014)

1106-92-2527 **Thierno Amadou Diallo*** (daoudayaboully@yahoo.fr), 1345 Shakespeare av apt 2E, Bronx, NY 10452, and **Justine lamberg** and **Urmi Ghosh-Dastidar**. *Studying Brain Connectivity using Weighted Graph Comparison.*

Studying brain components and its connectivity is an important field in neuroscience. While concepts of weighted graphs are widely used in many areas including computer, social, biological pathways, and air traffic networks, application of weighted graphs to study brain connectivity pattern is relatively new in the field of graph theory. In this project we focus on anatomical connectivity that connects nodes representing regions of interest (ROIs) and the weighted edges associated with structural connectivity i.e. the density fibers connecting ROIs. An adjacency matrix using connectivity weights between ROIs is created and Laplacian spectrum analysis and spectral clustering method are used to study the connectivity strength between and within two cerebral hemispheres. This work is supported by MAA NREUP 2014 grant. (Received September 16, 2014)

1106-92-2534 **Emili Moan*** (pricee4@winthrop.edu) and **Joseph Rusinko**. *Combinatorics of Linked Systems of Quartets.*

We apply classical quartet techniques to the problem of phylogenetic decisiveness and find a value k such that all compatible quartet systems with at least k quartets are decisive. Moreover, we prove that this bound is optimal and give a lower-bound on the probability that a compatible collection of quartets is decisive. (Received September 16, 2014)

1106-92-2545 **Charles Bergeron*** (chbergeron@gmail.com), Albany College of Pharmacy, and Health Sciences, 106 New Scotland Ave, Albany, NY 12208, and **Thomas R. Kiehl**. *Extracting connectivity patterns from neural spikes.* Preliminary report.

We are interested in the quantitative characterization of neuronal network development in cell cultures. We view this basic science as a necessary advancement towards improving regenerative therapies for neurological conditions. Our data comes from electrophysiological recordings of cell cultures grown on multielectrode arrays (glass plates embedded with 60 electrodes that can detect electrical activity). Presumably, by treating each culture as a weighted directed 60-node graph, we can infer how the tissue is interconnected, describe changes over time, assess the effect of other variables (cell density, presence of electrical stimulation, disease factors, application of pharmacological agents), and connect patterns to meaningful biological insights. However, our preliminary investigations have found that this inference is difficult to make. In tonic firing phase, the culture is in overdrive making it difficult to assess burst propagation through the network. In resting or quiescent phase, too few spikes are often detected, making it difficult once again to seize network properties. In this talk, we discuss our approach to this conundrum. (Received September 16, 2014)

1106-92-2569 **Reginald L McGee*** (mcgee3@purdue.edu), 150 N. University St, West Lafayette, IN 47907-2067, and **Mariya O. Krisenko**, **Robert L. Geahlen**, **Ann E. Rundell** and **Gregery T. Buzzard**. *A Computational Study of the Effects of Syk Activity on B Cell Receptor Signaling Dynamics.*

The kinase Syk is intricately involved in early signaling events in B cells and is required for proper response when antigens bind to B cell receptors (BCRs). Experiments using analog-sensitive versions of Syk (Syk-AQL) have better elucidated its role, but have not completely characterized its behavior. We present a computational model for BCR signaling, using dynamical systems, which incorporates both wild-type Syk and Syk-AQL. We investigate how manipulation of Syk-AQL can be used to modulate the downstream response associated with BCR stimulation. (Received September 16, 2014)

1106-92-2603 **Namhee Kim***, kimnamhee@gmail.com, and **Tamar Schlick**. *Mathematical RNA Biology: Graph Theory Approaches for RNA Structure Modeling and Prediction.*

Ribonucleic Acid (RNA) molecules become a prominent subject in modern biology due to recent discovery of their essential cellular roles. Understanding the mechanisms behind RNA's biological roles requires RNA tertiary (3D) structural knowledge. The modular and hierarchical RNA structures offer a solid ground for mathematical approaches, such as graph theory, to model and predict RNA 3D structures. Here, I present a hierarchical graph sampling approach to describe and predict RNA topologies by a coarse-grained sampling of 3D graphs guided by knowledge-based potentials derived from bend, twist, and compactness measures based on known structures. Sampling RNA graphs accelerates the global search for candidate RNA topologies, and the scoring potentials help select good candidates using a clustering approach. I also present recent applications of graph partitioning algorithms to discover the modularity of RNA networks and develop systematic design strategies for new RNA structures. (Received September 16, 2014)

1106-92-2604 **Ilona Reding*** (imr5662@uncw.edu), **Michael Kelley** (kelleyma1@appstate.edu), **Jonathan Rowell** (jtrowell@uncg.edu) and **Jan Rychtar** (j_rychta@uncg.edu). *Friend or Foe? A Continuous Ideal Free Distribution Approach to Dynamics of Individualistic, Cooperative, and Kleptoparasitic Populations.*

Populations distribute themselves throughout their habitat based upon a range of environmental factors. In this paper, we extend a reaction-advection model of ideally motivated populations to describe the local and regional consequences of interactions between three populations distinguished by their levels of intraspecific cooperation and interspecific competition and exploitation. These populations are taken as three stereotypical expressions of cooperative-exploitative behavior in resource collection and include: a baseline non-cooperative population that engages in interference competition, obligate cooperators who initially benefit from the presence of conspecifics, and - in a pathological example of defection - kleptoparasites who require heterospecifics to extract resources from the environment. Using both analytic techniques and simulations, we determine where different populations can coexist within the environment and investigate under what conditions one population will invade another. Kleptoparasites can initiate a long term dynamic instability when invading cooperators at high resource levels. Non-cooperators and cooperators are primarily allopatric with respect to one another and capable of resisting low-level invasions. (Received September 16, 2014)

1106-92-2622 **Jennifer Miller*** (jennifer.miller@trincoll.edu), Trinity College, Department of Mathematics, 300 Summit St, Hartford, CT 06106, and **Hwayeon Ryu**, **Zeynep Teymuroglu**, **Xueying Wang**, **Victoria Booth** and **Sue Ann Campbell**. *Clustering in inhibitory neural networks with nearest neighbor coupling.*

We consider networks of neurons that fire in synchronized clusters. We expect the clustering dynamics of a neural network to change if we vary the connections in use or the strength of these connections. Using phase model analysis, we examine the clustering dynamics of a network of neurons that are each connected to a small set of neighbors. We will focus on the conditions for stability of solutions when each neuron is coupled to its nearest or two nearest neighbors on each side. In some cases, the stability is independent of both the size of the network and the connection strengths, while others depend on the relative strengths of the different connections.
(Received September 16, 2014)

1106-92-2703 **Antonio Mastroberardino*** (axm62@psu.edu), **Ahmed Abdelrazec**, **Folashade Agusto** and **Lea Lanz**. *Two-sex model of the HIV/AIDS Epidemic in Cuba.*

Mathematical models of infectious diseases can help assess the effectiveness of prevention strategies such as random screening and contact tracing. In this talk, we present a mathematical model for the transmission dynamics of HIV/Aids in Cuba in which both prevention strategies play a role in reducing the incidence of HIV. The population is subdivided into male and female compartments to reflect the different gender dynamics. We present a qualitative analysis of the equilibria of the governing nonlinear system and discuss directions for future work. (Received September 16, 2014)

1106-92-2759 **Katherine Loraine Ehnis*** (kate.ehnis@ttu.edu), 1001 University Avenue, Apartment 2017, Lubbock, TX 79401, and **Stacy Philip** (stacy.philip@ttu.edu), **Carl R. Seaquist** (carl.seaquist@ttu.edu), **Fredrick Ramirez** and **Renato Gonik**. *Sonification of EEGs.* Preliminary report.

Ten patient Electroencephalogram (EEG) recordings were selected from a study conducted at a Lubbock hospital. These recordings include 2 normal and 8 abnormal EEGs, which were stripped of personal identifying information. Recent publications indicate that sonification (converting data to sound) allows the human ear to analyze series data and detect irregularities that might otherwise go unnoticed. Since brain rhythms are typically lower than the human hearing range, signal-processing techniques, including but not limited to modulation, Fourier transforms, wavelet analysis, and digital filtering, will be applied to convert EEGs to sound. Our objective is to demonstrate that in addition to traditional visual analysis, auditory acuity may be useful in the analysis of EEGs and aid in the early detection of abnormal EEG activity. The project will be a success if an algorithmic approach to sonification leads to the identification of important features of the EEGs by listening to the transformed signals.
(Received September 16, 2014)

1106-92-2835 **Ruijun Zhao*** (ruijun.zhao@mnsu.edu), 273 Wissink Hall, Department of Mathematics and Statistics, Minnesota State University, Mankato, Mankato, MN 56001. *Mathematical Modeling of Control Strategies of Malaria.*

Malaria is one of the most prevalent diseases worldwide and a leading cause of death in many developing countries. Malaria is caused by a parasite called Plasmodium, which is transmitted through mosquito biting between two hosts: humans and mosquitoes. Malaria can be treated with artemisinin-based combination therapies, however, the most effective ways in controlling the disease are through protective measures, such as insecticide-treated bed nets, indoor/outdoor spray, developing effective vaccines, etc.

In this talk, I will discuss a few mathematical models that we recently developed in understanding the effectiveness of these control strategies, particularly on insecticide-treated bed nets and vaccination. This work is jointly done through collaboration with Dr. Jemal Mohammed-Awel and Dr. Calistus Ngonghala, and others. (Received September 16, 2014)

1106-92-2864 **Yiqiang Zheng*** (zheng30@purdue.edu), Department of Mathematics, Purdue University, West Lafayette, IN 47907, and **Zhilan Feng**, Department of Mathematics, Purdue University, West Lafayette, IN 47907. *Dynamics of a seedling-herbivore model in presence of plant toxin defense.*

A simplified seedling-herbivore model with plant toxin defense is studied for mature forest systems. Chemical defense of plants plays an important role in the plant and herbivore interaction. Toxin-determined functional response models (TDFRM) have been studied to answer different ecological problems, including plants invasion, herbivore and wolf control and associated forest fire regime, etc. The seedlings of plants are main food resources for herbivores and are important in the regeneration of forests. The new system with explicit seedling class shows interesting bistability phenomenon and nonexistence of periodic solutions is proved, which is different from the previous research without explicit seedling class. However, the seasonal recruitment of seedlings is shown to result in the stable periodic solutions, which could be the source of oscillation of forest systems. (Received September 16, 2014)

93 ► Systems theory; control

1106-93-354 **Reza R Ahangar*** (reza.ahangar@tamuk.edu), P. O. Box 790, Kingsville, TX 78364. *Global Solutions to Optimal Automatic Control Systems.*

Abstract:

A nonanticipating operator of optimal automatic control system is developed. Conditions for existence and uniqueness of the solution for automatic control systems are provided. The global solution to the optimal automatic control of nonlinear nonanticipating dynamical systems is invsetigated. (Received August 24, 2014)

1106-93-507 **Jayant Singh*** (jayant.singh@ndsu.edu), 1125 17th Ave N Apt. 203, Fargo, ND 58102. *Stability Analysis of Discrete time Recurrent Neural Networks.*

Recurrent Neural Networks (RNN) have shown promise in diverse applications including Pattern Recognition, and Modeling of systems. We consider the problem of stability of RNN. One of the famous approaches is based on Theory of Absolute stability. It checks necessary and sufficient conditions for existence of quadratic Lyapunov function. But there exist stable systems, for which theory of Absolute stability does not hold true. We have proposed a new stability criteria, based on Reduction of Dissipativity Domain. Some new results in this area will be presented. (Received August 31, 2014)

1106-93-748 **Indranil SenGupta*** (indranil.sengupta@ndsu.edu), Department of Mathematics, NDSU Dept # 2750, Minard Hall 408E12, Fargo, ND 58108-6050, and **Semere Habtemicael**. *Ornstein-Uhlenbeck processes for geophysical data analysis.*

In this presentation a three parameter stochastic process, termed the Gamma-Ornstein–Uhlenbeck process, will be implemented to analyze geophysical data. Such non-Gaussian Ornstein-Uhlenbeck processes offer the possibility of capturing important distributional deviations from Gaussianity and make the model flexible of dependence structures. It will be shown that the Gamma-Ornstein-Uhlenbeck process is a possible candidate for earthquake data modeling and this model may be used to estimate parameters related to some major events-namely major earthquakes. (Received September 05, 2014)

1106-93-1056 **Dylan R Poulsen*** (dylan_poulsen@baylor.edu), **John M Davis** and **Ian A Gravagne**. *The Geometry of the Region of Uniform Exponential Stability on an Arbitrary Time Scale.*

We examine the regions of exponential stability and uniform exponential stability for first order, linear time invariant dynamic equations on an arbitrary time scale. While the region of exponential stability has been completely classified, a characterization of the theoretically important region of uniform exponential stability remains elusive. In this talk, we give a complete description of the best circular approximation at the origin to the region of exponential stability. We show that the circular region is not, in general, a subset of the region of uniform exponential stability. We provide, however, a mild condition on the time scale – *mean-stationarity* – which guarantees that this circular region is a subset of the region of uniform exponential stability. (Received September 10, 2014)

1106-93-1929 **Thanuka Hansameenu Pathiranage*** (hansameenu.wijenayaka@ttu.edu), Texas Tech University, Department of Mathematics and Statistics, Broadway and Boston, Lubbock, TX 79409. *Analysis of the Error in an Iterative Algorithm for Solution of the Regulator Equations for linear distributed parameter Control Systems.*

The regulator equations are a coupled pair of operator equations that arise in the geometric approach to regulation in systems and control. The main problems of control for this work consist of asymptotic tracking and disturbance rejection for linear parabolic distributed parameter systems. Our approach to solving problems of this type is geometric regulation in which control laws are obtained by solving the regulator equations. In this work we present the β-iteration method for obtaining approximate solutions of regulator equations for infinite dimensional linear control systems with bounded input and output operators in the Hilbert state space. A major advantage of this theory compared to previous works is that it can be applied to any smooth reference signal and an explicit error analysis is available for each step in the iteration. In this work, we describe the β-iteration method and present an analysis of the error for the iterative method. We also give theoretical estimates for its convergence. The convergence of the iterative method depends on the parameter β, ($0 <$ ¡1) and also on the exponential stability of the C_0 semigroup generated by the open loop plant. (Received September 15, 2014)

1106-93-2278 **David Jaures Fotsa Mbogne** (mjdavidfotsa@gmail.com), Department of Mathematics and Computer Science, ENSAI, University of Ngaoundere, Dang, Cameroon, and **Chris Thron*** (thron@tamuct.edu). *Optimal control of coffee-berry disease using both chemical and cultivational methods.*

We present a spatial diffusion-reaction model for the control of coffee-berry disease (athracnose) in a bounded domain. We use the model to simulate the combination of two different types of control strategies against anthracnose disease: continuous control (representing chemical means such as pesticides) and discrete-time control (which represents cultivational practices such as pruning and removal of mummified fruits). We have shown well-posedness of the model, and well as the existence of optimal control strategies with respect to a realistic cost function. We present and discuss the results of numerical simulations of both an aggregated version of the model and for the full model, in which optimal control strategies have been computed explicitly. (Received September 16, 2014)

1106-93-2662 **Elinor L Velasquez*** (elinor2015@gmail.com), 244 Fifth Ave., Suite E273, New York, NY 10001. *Preventative Analytics for Infectious Disease Pandemics.* Preliminary report.

An infectious disease pandemic is defined here to be an illness caused by an organism that infects many humans throughout the world. For illustrative purposes, we apply our novel definition of preventative analytics to the H1N1 2009 pandemic (flu) viral strain to measure the effectiveness of our novel platform of preventative analytics tools towards preventing a viral pandemic.

Previously, the emerging field of preventative analytics has been used in business and the IT sector to analyze data, showing time-dependent patterns, predicting a client's needs when used in business, producing alerts and estimating a scenario's noise. However, we enlarge this definition of preventative analytics to include an interactive component, creating a platform of computational tools based on preventative analytics, and inspecting their effectiveness in preventing a viral pandemic, as opposed to the traditional scientific methodology that typically analyzes the aftermath of a viral pandemic. The platform being presented follows a preventative analytics methodology, as well as a novel mathematical model describing the 2009 H1N1 2009 flu pandemic. (Received September 16, 2014)

94 ► Information and communication, circuits

1106-94-627 **Venkatesan Guruswami*** (guruswami@cmu.edu). *Polar codes: Reliable communication with complexity polynomial in the gap to Shannon capacity.*

Shannon's monumental 1948 work laid the foundations for the rich fields of information and coding theory. The quest for efficient coding schemes to approach Shannon capacity has occupied researchers ever since, but the theoretical problem of approaching capacity arbitrarily closely with polynomial complexity remained open except in the special case of erasure channels.

In 2008, Arikan proposed a novel method for constructing capacity-achieving codes based on channel polarization. In this talk, I will begin by briefly surveying Arikan's celebrated construction of polar codes, and then discuss our proof (with P. Xia) that, for all binary-input symmetric memoryless channels, polar codes enable reliable communication at rates within $\epsilon > 0$ of the Shannon capacity with block length (delay), construction complexity, and decoding complexity all bounded by a **polynomial** in the gap to capacity, i.e., by $\mathrm{poly}(1/\epsilon)$. Polar coding gives the *first explicit construction* with rigorous proofs of all these properties; previous constructions were not known to achieve capacity with less than $\exp(1/\epsilon)$ decoding complexity. More recently, in work with A. Velingker, we also extended this result for channels with non-binary inputs from a prime-sized alphabet. (Received September 03, 2014)

1106-94-649 **Abdulla Eid*** (eid1@illinois.edu), PO Box 32038, Isa Town, 00973, Bahrain, and **Duursma**. *Using concatenated algebraic geometry codes in channel polarization.*

In this talk, we will be talking about using concatenated algebraic geometry codes as polar codes. Polar codes were introduced by Arikan in 2008 and are the first family of error-correcting codes achieving the symmetric capacity of an arbitrary binary-input discrete memoryless channel under low complexity encoding and using an efficient successive cancellation decoding strategy. Recently, non-binary polar codes have been studied, in which one can use different algebraic geometry codes to achieve better error decoding probability. We will start this talk by defining what polar codes and channel polarization are and then we will talk about the performance of binary polar codes that are obtained from non-binary algebraic geometry codes using concatenation. For binary polar codes (i.e. binary kernels) of a given length n, we compare numerically the use of short algebraic geometry codes over large fields versus long algebraic geometry codes over small fields. We find that for each n there is an optimal choice. For binary kernels of size up to 1,800 a concatenated Reed-Solomon code outperforms other choices. For larger kernel sizes concatenated Hermitian codes or Suzuki codes will do better. (Received September 04, 2014)

1106-94-1020 **Kristin E. Lauter*** (klauter@microsoft.com). *Network Coding and Applications.*

Network Coding has been proposed as a technique to maximize throughput in peer-to-peer content distribution networks. While optimizing for throughput, such systems also become extremely vulnerable to pollution attacks, where garbage is injected into the network by a malicious node and recombined with the content. This talk will survey some applications of Network Coding and some solutions from cryptography which help defend against pollution attacks. (Received September 09, 2014)

1106-94-1065 **Jessica OShaughnessy*** (joshaugh@su.edu), Shenandoah University, 1460 University Drive, Winchester, VA 22601. *Convolutional Codes from Group Rings.*

Units in the group ring have been used to construct several types of codes. This type of construction gives a strong algebraic component to coding. A new construction is proposed for constructing convolutional codes from units in the group ring. This is an extension of a previous convolutional code construction proposed by Hurley in 2009, with the intention of expanding the number of convolutional codes that can be constructed using units in the group ring. It uses a known isomorphism between group rings and rings of matrices to construct generator matrices for convolutional codes. The codes allow for less storage requirements for larger codes and are being considered for extension to other types of codes, such as LDPC convolutional codes and turbo codes. (Received September 10, 2014)

1106-94-1356 **Steve Szabo*** (steve.szabo@eku.edu), steve.szabo@eku.edu, and **Felix Ulmer** (felix.ulmer@univ-rennes1.fr), Rennes, France. *Dualilty Preserving Gray Maps and Self-Dual Codes over Rings.*

We present various conditions on a finite ring that the allow possibility of finding good self dual codes over one of its subrings. (Received September 15, 2014)

1106-94-1880 **Qiyu Sun*** (qiyu.sun@ucf.edu), Department of Mathematics, University of Central Florida, Orlando, FL 32816. *Sparsity and spatial localization of spatially decaying systems.* Preliminary report.

In this talk. we consider how to measure sparsity and spatial localization of spatially decaying systems. We will develop Banach algebra technique to study their distributed sampling and optimal control. (Received September 15, 2014)

1106-94-1892 **Tuan A Le*** (let5@students.rowan.edu), Department of Mathematics, Rowan University, 201 Mullica Hill Rd., Glassboro, NJ 08028, and **Hieu D Nguyen** (nguyen@rowan.edu), Department of Mathematics, Rowan University, 201 Mullica Hill Rd., Glassboro, NJ 08028. *Decoding and Merging of Helberg Codes.* Preliminary report.

Helberg codes are capable of correcting multiple insertion/deletions errors. These codes are a generalization of the number-theoretic Levenshtein code, which is capable of correcting a single insertion/deletion. In this talk, we present an algorithm to decode the Helberg code as well as a construction to merge two Helberg codebooks to obtain a higher code rate. (Received September 15, 2014)

1106-94-1968 **Sinan Gunturk*** (gunturk@cims.nyu.edu) and **Evan Chou**. *Distributed noise-shaping and beta encoding for general sampling systems.* Preliminary report.

This talk is on a new class of noise-shaping quantization and reconstruction algorithms for frame-based as well as compressive measurement systems. With these algorithms, we show how to achieve, for any given quantization alphabet size, near-optimal accuracy for Gaussian frames and compressive sampling systems as well as some classical deterministic frames in both finite and infinite dimensions. (Received September 16, 2014)

1106-94-2011 **Catherine A Bliss*** (catherine.bliss@uvm.edu), Vermont Center for Complex Systems, Dept. of, Mathematics, Vermont Advanced Computing Core, 16 Colchester Ave., Burlington, VT 05404, **Christopher M Danforth** (chris.danforth@uvm.edu), Vermont Center for Complex Systems, Dept. of, Mathematics, Vermont Advanced Computing Core, 16 Colchester Ave., Burlington, VT 05405, and **Peter Sheridan Dodds** (pdodds@uvm.edu), Vermont Center for Complex Systems, Dept. of, Mathematics, Vermont Advanced Computing Core, 16 Colchester Ave., Burlington, VT 05405. *Estimation of global network statistics from incomplete data.*

Complex networks underlie an enormous variety of social, biological, physical, and virtual systems. A profound complication for the science of complex networks is that in most cases, observing all nodes and all network interactions is impossible. Previous work addressing the impacts of partial network data is surprisingly limited, focuses primarily on missing nodes, and suggests that network statistics derived from subsampled data are not suitable estimators for the same network statistics describing the overall network topology. We generate scaling methods to predict true network statistics, including the degree distribution, from only partial knowledge of nodes, links, or weights. Our methods are transparent and do not assume a known generating process for the network, thus enabling prediction of network statistics for a wide variety of applications. We validate analytical results on four simulated network classes and empirical data sets of various sizes. We perform subsampling experiments by varying proportions of sampled data and demonstrate that our scaling methods can provide very good estimates of true network statistics while acknowledging limits. Lastly, we apply our techniques to a set of rich and evolving large-scale social networks, Twitter reply networks. (Received September 15, 2014)

1106-94-2657 **Christine A. Kelley*** (ckelley2@math.unl.edu) and **Kathryn Haymaker**. *Designing error correcting codes for flash memories.*

Error correction for the flash memory channel is a topic of current interest due to the prevalence of flash memories in many current storage devices. We consider the standard setting of two bits per cell (MLC) and three bits per cell (TLC) flash cells, where the different bits stored in a cell are prone to unequal error rates. This talk focuses on the design of low-density parity-check (LDPC) codes for this application. We show how the degree distribution of the check nodes to the different variable node types affects performance, and present a construction of LDPC codes that have optimized check node degree distributions in this respect. Time permitting, we will present work on the design of non-binary LDPC codes for such applications. (Received September 16, 2014)

1106-94-2880 **Swanand Kadhe***, kswanand1@tamu.edu, and **Alex Sprintson**, spalex@tamu.edu. *Explicit Constructions of Information-Theoretically Secure Regenerating Codes for Distributed Storage.*

Classical codes such as Reed-Solomon codes are not well suited for large distributed storage systems like cloud storage because these codes are highly suboptimal in terms of *repair bandwidth* – amount of data downloaded while repairing a failed storage node. *Regenerating codes* are a class of codes that optimally trade-off storage space per node for reducing the repair bandwidth. We focus on designing regenerating codes that are information-theoretically secure against a passive eavesdropper (possessing unbounded computational power) that can observe a limited subset of storage nodes. We demonstrate that achieving good security properties requires that, for the codewords exposed to the eavesdropper, the minimum distance is maximized. However, the goal of achieving low repair bandwidth limits the minimum distance of a code. We take an existing family of regenerating codes and present explicit outer code construction based on coset coding that secures the underlying regenerating codes. We also consider the security properties of another class of codes, namely, *locally repairable codes* that minimize the number of nodes participating in the repair process, and bring out connections with matroid theory. (Received September 17, 2014)

1106-94-2908 **Igor Zelenko***, zelenko@math.tamu.edu, **Muxi Yan**, mxyan@tamu.edu, **Alex Sprintson**, spalex@tamu.edu, and **Swanand Kadhe**, kswanand1@tamu.edu. *On MDS Codes with Constrained Generator Matrices and Related Problems.*

Our aim is to design generator matrices of Maximum Distance Separable (MDS) codes such that each row of the generator matrix has a specific support. More specifically, we consider an (n, k)-MDS code for which each row of its generator matrix contains up to $k-1$ zeros at certain places, and the elements at the remaining places can be assigned any values from the underlying finite field. We call such a generator matrix as the constrained generator matrix G_{con}. It can be shown that if G_{con} does not contain an $l \times m$ zero sub-matrix such that $l + m = k + 1$, then randomly choosing the values of non-zero elements over a finite field of sufficiently large size results in an MDS code with high probability. We say that G_{con} is feasible if it is possible to complete it to an MDS code. We conjecture that it is possible to linearly transform a Vandermonde matrix to obtain the constrained generator matrix with high probability for any feasible matrix G_{con}. We verify this conjecture for a large number of cases. This conjecture admits a number of reformulations that lead to interesting conjectures in algebraic geometry, abstract algebra and number theory. In particular, our method to verify it is based on a purely geometric reformulation of the problem. (Received September 17, 2014)

97 ► Mathematics education

1106-97-35 **Jhemson Caaway Elis*** (jhemson_elis@yahoo.com), Ambulong, Batabgas City, Philippines, 4200 Batangas City, Batangas, Philippines. *Instructional Game In Teaching Algebra For High School Students: Basis For Instructional Intervention.* Preliminary report.

The study aims to determine the profile of the respondents, performance of the control and experimental groups through pretest and posttest, impact of the instructional game used as instructional intervention in teaching, significant difference between the level of performance of the two groups of respondents in their pre-test and posttest results, and the proposed instructional intervention. Certain approach was used that corresponds to the main objective of this research which is to determine the effectiveness of the instructional game used as instructional intervention in teaching algebra for high school students. The study recommended that mathematics teacher should made an instructional games for the students with fun and enjoyment, mathematics education program supervisor should give training for teachers on how to conceptualized mathematics intervention, meaningful activities must be provided to sustain the student's interest in learning, students must be given time to have fun at the classroom through playing while learning, future researcher must continue conceptualizing of some mathematics intervention to suffice the needs of the students, and teachers should inculcate more educational games so that the discussion will be successful and joyful. (Received May 13, 2014)

1106-97-170 **Lindsay Hixon*** (leh031@shsu.edu), SHSU Mathematics & Statistics Department, Box 2206, Huntsville, TX 77341, and **Megan Brown**, **Alisha Dunkle**, **Zach Silbernick** and **Nicole Yoder**. *Statistical Content in Elementary Textbooks.*

We investigated the nature and extent of the statistical content in five U.S. textbook series for students in grades 1-5. Using the *Guidelines for Assessment and Instruction in Statistics Education (GAISE) Report*, we coded statistics tasks by phase: Formulate a Question, Collect Data, Analyze Data, and Interpret Results. The Analyze Data phase was further divided into four categories: Read a Display, Perform a Mathematical Calculation, Construct a Display, and Use Other Statistical Reasoning. We also noted the location of the statistics tasks and the types of displays used. Finally, we noted which Common Core State Standards and Texas Essential Knowledge and Skills (TEKS) were addressed. The treatment of statistics varied by series. The two series that met all the TEKS had most of their statistics tasks at the end of the textbooks. The series that addressed the fewest standards was statistics-heavy. The books in our sample predominantly focused on Analyzing Data, which may inadvertently restrict opportunities for students to generate and interpret data. Our research was supervised by Dr. Dusty Jones (Sam Houston State U.) and funded by NSF grant DMS-1262897. (Received August 04, 2014)

1106-97-226 **Joshua A Taton*** (jtaton@upenn.edu), **Amy N Myers**, **Cathryn Anderson** and **Stephen Bartholomew**. *Drawing on Effective Professional Development Research: Using a Pedagogical-Content Model in the Philadelphia Area Math Teachers Circle (PAMTC).*

A growing body of educational research has demonstrated that effective professional development for teachers includes addressing elements of both content and pedagogy, especially the pedagogy that is embedded within content and vice-versa. This literature also draws upon what researchers now know about the effectiveness of learning within communities and engaging in the active construction of knowledge. In the Philadelphia Area Math Teachers' Circle (PAMTC), we aim to make transparent for teachers some of the tacit pedagogical-content features of the American Institute of Mathematics' approach to adult-learning within math circles; in particular, beyond modeling active-learning and problem-solving, we also engage in discussions of not only "how to think like a mathematician" and "how to be a successful problem-solver," but also "how to connect PAMTC problems to curriculum / content" and "how to facilitate high-quality, student-centered discussions." This pedagogical-content model, we conjecture, enhances teachers' experiences within our group—supporting their mathematical growth in problem-solving, as well as providing actionable tools for use in their own classrooms. In this session, we present our model and explore what some of our teachers have said about our approach. (Received August 12, 2014)

1106-97-233 **Andrew Bucki*** (ajbucki@langston.edu), Department of Mathematics, Langston University, Langston, OK 73050, and **Abebaw Tadesse**. *A successful new educational program in Mathematics for STEM-C.* Preliminary report.

In this talk we will present successfully tested New Educational Program in Mathematics (NEPM) for STEM-C disciplines. The program employs an innovative and transformative NEPM based on computational thinking with partnership and programming approach to the pedagogy and content of the traditional methods of teaching and learning mathematics including computing sciences.

The fundamental difference between the traditional educational program and the proposed one is that our program makes students active learners, constantly thinking, as if they were talking to a computer instead of rotely transcribing solutions to worked out examples by the instructor. Our approach thus makes it natural to think that they have to create programs to communicate with a virtual computer which, in turn, allows them to translate a definition or property or formula into a computer program. This communication of a concept to a virtual computer is key to increasing the student's conceptual understanding of a mathematical idea. A positive byproduct of this approach may be a greater inclination to further study of computer programming by students.

Some examples illustrating the ideas of the program will be presented. (Received August 13, 2014)

1106-97-240 **Natali Hritonenko*** (nahritonenko@pvamu.edu), Department of Mathematics, Prairie View, TX 774, TX 77446-0519. *Warm-ups and games as tools for better understanding mathematical subjects.*

Every mathematical discipline has a demanding curriculum and requires covering a variety of topics, each of which needs a strong foundation of its prerequisite courses. Sometimes, the latter is not as it had been desired, and some students have barely passed the prerequisites and are overwhelmed with new courses and other activities. They just jump from class to class and their thoughts might be still in the previous class. How does an instructor switch the students' attention to their current class? How do they refresh the previously discussed topics, review fundamentals, and prepare students to learn new topics? Various pedagogical ideas and techniques have been suggested since ancient times. Implementation of warm-ups, games, and bonus problems is one of them. Their description and examples, provided at different levels of mathematical courses, will be presented. The benefits and challenges of these activities from assessment perspectives and students' eyes will also be discussed. (Received August 13, 2014)

1106-97-248 **Matthew G Jones*** (mjones@csudh.edu). *Mathematical Authority and Inquiry-Based Learning.*

This talk will describe Inquiry-Based Learning (IBL) and its interaction with notions of mathematical authority. The talk will begin with a brief history of IBL, from Moore to current practice, and include a working definition of IBL. The talk will also explore the interplay between IBL and notions of mathematical authority, centering on the questions of, When is a proof considered valid? and, Who can validate a proof? There will also be a discussion of the research on students' views of mathematical authority and the impact of these on student achievement. (Received August 14, 2014)

1106-97-349 **Amy Cohen*** (acc@math.rutgers.edu), Math Dept., Hill Center, 118 Frelinghuysen Road, Piscataway, NJ 08854. *Math Teacher Circles: Sustaining an NSF Math Science Partnership.*

The NJ Partnership for Excellence in Middle School Math (PEMSM) is a Math Science Partnership, NSF0934079, which has supported over 100 teachers in 4 cohorts. Each cohort completes a 7-course 2-year Institute in which teachers deepen their understanding of the math they teach and the pedagogy they use. MSP grants require projects to find ways to sustain their activities. Since most Institute math course were structured around group work on problems that were engaging, slightly challenging, but ultimately both accessible and relevant, the MTC model was an attractive option. A team of NJ PEMSM personnel learned to organize MTCs at a 2013 workshop sponsored by AIM and MAA. A year later, with funding from AIM and from the Rutgers Math Department, PEMSM offered two demonstration MTC sessions. 45 PEMSM teachers attended; most expressed interest in attending more. Current plans call for MTC sessions in two geographically convenient locations and a leadership development workshop for participants who may later start district-based MTC's working with mathematicians from IHE's in central NJ. (Received August 24, 2014)

1106-97-372 **Ellina Grigorieva*** (egrigorieva@twu.edu), PO Box 425262, Denton, TX 76204. *Teaching Solving Complex Problems and Preparing Math Olympiad Winners.*

Teaching Solving Complex Math Problems and Preparing Math Olympiad Winners

The goal of this project is to prepare highly knowledgeable mathematics teachers nationwide and particularly in Texas. It is known that the mathematics preparation of high school students is not satisfactory in that prodigious students are not uniformly nurtured. The author adapted and implemented pedagogy and course materials designed specifically to address the issues above. Her method is based on showing students connection between different fields of mathematics and even different subjects. Recent trends in math education call for the increasing the number of math teachers. However, quantity does not mean quality. In response, one objective of this project is to develop a sequence of integrated courses for future teachers where students learn different methods of solving complex math problems, how to do proofs and also how to give this knowledge to their students and develop students interest in math not by playing games in the classrooms, but making math problems solving in the class as "addictive" as playing video games for some kids (Received August 25, 2014)

1106-97-432 **James Tanton*** (tanton.math@gmail.com), 5033 E Turquoise Ave, Paradise Valley, AZ 85253. *Quirky Mathematics: Its Joy and its Pedagogical Value.*

Great depth of understanding often comes from pushing concepts to the edge – and beyond! In this presentation we'll examine a sample of curriculum tidbits quirkily pushed to the arena of creative and innovative exploration. How many degrees are in a Martian circle? What is pi for a square? Let's explore squine and cosquine. Can we complete the triangle rather than complete the square? (What is the quadratic formula in Klingon?) If $0.9999\ldots = 1$, then what is $\ldots 99999$? Can we bring back the vinculum please? Simple and natural turns to standard classroom questions provide an opportunity to unite powerful math circle doing and K-12 classroom practice—a goal that is beautifully aligned with the aim and purpose of the Common Core State Standards. (Received August 28, 2014)

1106-97-433 **Dev P. Sinha***, dps@uoregon.edu, and **Tricia Bevans**, thbevans@uoregon.edu. *Coherent use of bases in preservice elementary content courses.*

Using different bases to represent numbers has often been included in preservice elementary content courses. Traditionally the rationale has been to help ensure that the students understand the standard algorithms of arithmetic. Some reformers see this as of less value than other activities, and have jettisoned the topic.

We have been developing a more coherent use of different bases, in part with an eye towards deeper reflection on the Common Core. For example, we do skip-counting activities, using unit-form names for numbers in different bases (e.g. "three sevens and four") as a way to highlight how place value is reinforced by skip counting (2.NBT.2).

We will share a wide range of activities through which work in different bases reinforces other significant mathematical work: standard arithmetic; the Russian Peasant multiplication algorithm; divisibility rules; base-b-imal representation of numbers. We also share what is to our knowledge a novel way to represent numbers in bases greater than ten, discovered by a twelve-year-old, which opens up a some interesting activities. A culmination activity is finding and interpreting the base-two-imal representation of the square root of two, using it to place the square root of two on a base-two number line. (Received August 28, 2014)

1106-97-533 **Mike Nakamaye*** (nakamaye@math.unm.edu). *Transformational Geometry in the High School Curriculum.* Preliminary report.

Rigid motions of the plane play a fundamental role throughout the development of the geometry domain in the Common Core State Standards for Mathematics. Reflections are introduced in elementary school and in the eighth grade students systematically study different rigid motions of the plane and their impact on points and shapes. In high school, these rigid motions are used to establish the key congruence criteria for triangles.

This important conceptual shift in understanding congruence offers many opportunities to make important connections with other parts of the high school curriculum, including:

- Transformations are important examples of functions and offer many rich opportunities for students to work with functions whose domain and range are not the real numbers or a subset of the real numbers.
- Transformations can be described algebraically and can form a powerful tool for analyzing some functions such as quadratics.
- Transformations are at the heart of symmetry, a topic of vital interest in nature and in mathematics.

In this talk, we will explore some of these important connections which rigid motions have with the rest of the K-12 curriculum. (Received September 01, 2014)

1106-97-550 **Junalyn Navarra-Madsen*** (jnavarramadsen@mail.twu.edu), PO Box 425886, Denton, TX 76204. *Successes and Challenges in Teaching University-Level Mathematics.*

Teaching university-level mathematics in the 21st century can be sometimes daunting. Given the widening "high school to college" gap in mathematical preparation of students, it is more difficult to teach even the lowest level university mathematics courses. An increasing number of developmental math courses are starting to be a norm in most universities. In this paper, the author provides specific examples of strategies she incorporated in teaching some of her mathematics classes where she has experienced some successes and some challenges. (Received September 02, 2014)

1106-97-594 **Frank Morgan*** (fmorgan@williams.edu). *Teaching Developmental Algebra at Berkshire Community College.*

I spent my 2014 fall sabbatical from Williams College as Visiting Professor (teaching developmental algebra) and Special Assistant to the President (for academic community) at Berkshire Community College. Here's what I learned. (Received September 03, 2014)

1106-97-687 **Michael Nakamaye*** (nakamaye@math.unm.edu). *Mathematics of MTC's spanning the K-20 Spectrum.*

A hallmark of Math Teachers' Circle problems is to stimulate multiple productive approaches, often stimulating deep thinking and sometimes leading to new mathematical discoveries. In this talk we will look in depth at some Math Teachers' Circle problems, focusing on

- How they relate to the Common Core State Standard for Mathematics
- How they naturally lead to interesting mathematics at the high school and undergraduate level
- How they lead to unsolved mathematical questions

(Received September 04, 2014)

1106-97-715 **Scott Baldridge*** (sbaldrid@math.lsu.edu), Department of Mathematics, 380 Lockett Hall, Louisiana State University, Baton Rouge, LA 70803. *Coherence in geometry: Preparing students for transformational geometry.*

The prominent inclusion of transformational geometry in the Common Core State Standards sets the standards apart from every other set of standards that came before it. The inclusion is a structural change with far ranging consequences that reverberate throughout K-12 and college, which is one of the main reasons why publishers cannot simply rearrange their textbooks to remain CCSS compliant. In this talk, I will discuss the definitions, axioms, theorems, and problems embedded into the Eureka Math/EngageNY curriculum that not only prepare students for discussing transformational geometry by eighth grade, but help them to take full advantage of this powerful tool in high school and beyond. (Received September 05, 2014)

1106-97-761 **Michelle A Manes*** (mmanes@math.hawaii.edu), University of Hawaii Mathematics Department, 2565 McCarthy Mall, Keller 401A, Honlolulu, HI 96822. *Modeling with Mathematics: MTC sessions that encourage and illuminate this CCSS Mathematical Practice.*

The Math Teachers' Circle of Hawaii (MaTCH) is in its fourth year. We have found that our teacher participants have a lot of experience with and ideas about many of Common Core State Standards for Mathematical Practice, but MP4 "Model with Mathematics" is often a source of confusion for them. Many teachers interpret this to mean "demonstrate a problem solving method, and then have students mimic your solution on related problems."

Over the past two years, we have designed a few sessions specifically targeting the idea of "mathematical modeling": A session on bioacoustics, a session on bee population dynamics, several sessions inspired by the work of artist Sue Fuller, and a session on the traditional Hawaiian game 'Ulu Maika are just a few examples.

In this session, I will share descriptions of these sessions along with some of our participant feedback regarding their developing understanding mathematical modeling. (Received September 05, 2014)

1106-97-932 **Lina Wu*** (lwu@bmcc.cuny.edu), 529 West 42nd Street Apt. 5K, New York, NY 10036, and **Annie Han** (yhan@bmcc.cuny.edu), 199 Chambers Street, New York, NY 10007. *The Origin, Development, and Dissemination of Differential Geometry in Mathematics History.* Preliminary report.

Geometry came from solving problems in Astronomy related to "Earth Measurement". The origin of Differential Geometry began with geometric properties of curves and surfaces in space at the beginning of the 19th century. The ancient study was related to Calculus techniques, Carl Friedrich Gauss on Gauss Curvature, Bernhard Riemann on Riemannian Manifold in 1854 and Albert Einstein's General Relativity Theory between 1907 and 1915. The contemporary study focused on geometric structures of various manifolds. It was enhanced by Shiing-Shen Chern on Chern's Characteristic Classes, Shing-Tung Yau on Calabi-Yau Manifold and Minimal Surfaces Theory, Henry Wente on Wente Torus as the Constant-Mean-Curvature Surface, Shihshu Walter Wei on p-Harmonic Theory, etc. (Received September 08, 2014)

1106-97-1142 **Najat Ziyadi*** (najat.ziyadi@morgan.edu), Department of Mathematics, Morgan State University, 1700 East Cold Spring Lane, Baltimore, MD 21251, and **Shahpour Ahmadi**, Department of Mathematics, Morgan State University. *Scientific Teaching/Active Learning in STEM Classrooms: Context, Challenges and Application.*

In this talk on scientific teaching framework, we define active learning approach and highlight its challenges in STEM classrooms. In addition, we use two examples to illustrate applications of active learning method in a mathematics classroom. (Received September 11, 2014)

1106-97-1184 **Jeffrey Humpherys*** (jeffh@math.byu.edu), Department of Mathematics, TMCB 386, Provo, UT 84604. *Modeling Across the Undergraduate Curriculum.*

We report on the findings of the undergraduate group for the Modeling Across the Curriculum II Workshop. We discuss the curricular gaps between the status quo in academia today and what is needed to meet the challenges of a globally competitive workforce in the 21st Century. Along the lines of the two NRC reports Mathematical Sciences 2025 report and its companion piece Fueling Discovery and Innovation, we discuss several recommendations that came from our group. (Received September 11, 2014)

1106-97-1214 **Rachel Levy*** (levy@hmc.edu), Mathematics, Harvey Mudd College, 301 Platt Blvd, Claremont, CA 91711. *Mathematical Modeling in the Early Grades.*

The early grades group from the Modeling Across the Curriculum workshop focused on the question, "What can mathematical modeling look like in the K-6 curriculum?" The new Common Core State Standards for Mathematics indicate that Modeling with Mathematics is an important mathematical practice, but the practice could be implemented many ways within the curriculum. This session will focus on some issues that are particular to the early grades and describe a new NSF funded program focused on work with Elementary School teachers on mathematical modeling. (Received September 11, 2014)

1106-97-1223 **Katherine Morrison*** (katherine.morrison@unco.edu), Ross Hall 2239/ CB 122, University of Northern Colorado, 501 20th St, Greeley, CO 80639, and **Gulden Karakok**. *Northern Colorado Math Teachers' Circle's Implementation of Common Core State Standards.*

Northern Colorado Math Teachers' Circle was formed in 2011 to engage local middle school math teachers in problem-solving tasks. Thus far, we have held 6 evening sessions each school year and two four-day summer immersion workshops. In our sessions, we have selected tasks that are appropriate for our teachers but also typically align with CCSS for grades 5-8. The post-survey conducted at the end of our first summer workshop reflected teachers' appreciation of suitable tasks, however they requested more opportunities to discuss implementation of problem solving in their classrooms. In this talk, we will share some pedagogically oriented PD activities that we integrated into our second summer workshop in response to these requests. We will also describe the balance we attempted to strike in the tasks we chose for our sessions in order to provide a number of tasks that were interesting and challenging to the teachers as mathematicians while also providing tasks that directly tied to the standards. Finally, we will share how some of our MTC participants integrated tasks from our sessions into their classrooms and how they adjusted their teaching practices to provide meaningful mathematical discourse among their students that were similar to their experiences at our sessions. (Received September 11, 2014)

1106-97-1261 **Peter R Turner*** (pturner@clarkson.edu). *The SIAM-NSF Modeling across the Curriculum Initiative.*

This talk will begin with background information on the Modeling across the Curriculum, MaC, initiative, an NSF-sponsored SIAM program aimed at advancing modeling and computational applied mathematics throughout the educational spectrum. The main focus will be on the second MaC workshop held in January 2014 and the resulting report and recommendations. The subsequent talks will go more deeply into the three primary themes of the workshops. (Received September 11, 2014)

1106-97-1461 **Thomas J Clark*** (tom.clark@dordt.edu), Dordt College, 498 4th Ave NE, Sioux Center, IA 51250. *Developing the Horizon Content Knowledge of Teachers through a Math Teachers' Circle.*

Although much of the training pre-service mathematics teachers receive is either in mathematical content or educational theory and pedagogy, research indicates that mathematical knowledge for teaching (MKT), which lies in a sense at the intersection of the two, is a factor in teacher quality. Unfortunately, none of the recent improvements in teacher preparation necessarily affect in-service mathematics teachers.

One successful program affecting in-service teachers nationwide is the Math Teachers' Circle Network. One strand of MKT that I believe math teachers' circles are in a position to affect is Horizon Content Knowledge (HCK). Although taking advanced mathematics courses may improve HCK, often those courses are not taught in light of school mathematics, so it is left for the students to make the connections for themselves.

In this talk I will discuss my work in starting a math teachers' circle in NW Iowa with a goal of developing horizon content knowledge in teachers. I will share some of the materials I have used which make connections between school and advanced mathematics in a genuine way as well as its effect on the HCK of the participants. (Received September 13, 2014)

1106-97-1468 **Hyman Bass*** (hybass@umich.edu). *Mathematical connections: Curricular and cognitive.*

I have designed a mathematics course, for pre-service teachers and other math majors, that aims to develop math connections, both across topics in the school curriculum, where these connections are often left invisible, and in problem solving, where I try to develop what I call "connected mathematical thinking." Topics of the course include: place value; modular arithmetic; rudimentary abstract algebra; geometric and algebraic structure of the number line; basic combinatorics; polynomials; and discrete calculus. Some sample connections: In the decimal expansion of a fraction, the wait time and period have natural modular arithmetic meanings; similarly for the "divisibility tests." Discrete calculus, an analogue of calculus, generalizes the pattern finding activities common in school mathematics, it is closely linked to the Binomial Theorem, and it interprets power sums of consecutive integers as discrete integrals, thereby affording general methods of computation. "Cross domain problems," i.e. problems whose solution draws on resources from more than one mathematical domain, prompt one kind of connected thinking. "Common structure problem sets" call for solving a collection of problems and then identifying some mathematical structure that underlies each of them. (Received September 13, 2014)

1106-97-1490 **W. James Lewis*** (jlewis@unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68502, and **Angie Hodge** and **Michelle Homp**. *Using Math Teachers' Circles to Sustain a K-16 Partnership among Teachers and University Faculty.* Preliminary report.

Two NSF funded Math Science Partnerships have made it possible to offer graduate coursework to large numbers of Nebraska middle level and high school mathematics teachers. Math Teachers' Circles have been an important vehicle for offering ongoing professional development for math teachers and sustaining the partnerships that began as a result of the MSPs. Together we are supporting several Math Teachers' Circles including one in an urban environment and one that uses a distributed MTC model in rural Nebraska. In this session, we will share how different universities have used Math Teachers' Circles as a vehicle to support lasting partnerships based upon the needs of diverse communities. (Received September 13, 2014)

1106-97-1501 **W. James Lewis*** (jlewis@unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68502. *Seeking Coherence in the Mathematical Education of Elementary Teachers.* Preliminary report.

The Mathematical Education of Teachers II recommends that courses and professional development experiences for mathematics teachers should develop the habits of mind of a mathematical thinker and problem-solver, such as reasoning and explaining, modeling, seeing structure, and generalizing. Courses should also use the flexible, interactive styles of teaching that will enable teachers to develop these habits of mind in their students. At the University of Nebraska-Lincoln, the mathematical education of elementary teachers is viewed as an interdisciplinary partnership that involves mathematicians, mathematics educators, and master teachers. We want elementary teachers to believe that mathematics is something you think about – that mathematical situations can be reasoned about on the basis of a few basic principles. Our goal is to present mathematics as a coherent body of knowledge that helps teachers develop the ability to reason about elementary mathematics. (Received September 13, 2014)

1106-97-1603 **Katie Fowler*** (kfowler@clarkson.edu) and **Katherine Socha** (ksocha@parkschool.net). *Modeling and Secondary School STEM Education.*

Secondary schools in the US offer their students a varying level of access to rich mathematical modeling topics. Some schools offer entire courses centered on mathematical modeling practices while others offer very little. Our working group has developed a set of recommendations for questions to investigate and tasks to carry out that might help infuse models and modeling across the curriculum. Please join us to explore these ideas further in a constructive conversation. (Received September 14, 2014)

1106-97-1634 **Kate Nowak*** (katherine.nowak@gmail.com) and **Patrick Callahan** (callahan.web@gmail.com). *Unit and Course Blueprints: Tools for building coherence.*

The Common Core State Standards in Mathematics are not a list of topics to be covered and checked off a list, but rather a description of the mathematics students are supposed to achieve through a series of instructional experiences.

One way to begin to design curriculum is to identify multi-week curricular units that form a natural pedagogical flow based on mathematical coherence. We recently spent nearly a year constructing such units for high school courses that can form either a traditional or integrated pathway.

One does not build a decent house by grabbing a bunch of materials and hammering away at them, but uses a blueprint that shows the plan and structure. Similarly, one does not build decent curricula by grabbing a bunch of lessons and activities and grouping them together. Our Course and Unit Blueprints are a tool to show a way to structure the standards in a mathematically and pedagogically coherent way.

We will provide examples, discuss the design, and share some lessons learned through the process of building unit blueprints for all of the high school standards. We will also discuss how these tools could be used in pre-service and in-service teacher education. (Received September 14, 2014)

1106-97-1756 **Sandra J Schroeder*** (s-schroeder@onu.edu). *My Experiences from Organizing a Mathematics Workshop for Teachers in Belize.* Preliminary report.

While applying for a sabbatical to help update and rewrite some mathematics textbooks in Belize, it was suggested by my contact in Belize that I also hold a workshop for their teachers (equivalent to our K-8 grades). Since I have been teaching the mathematics content to early and middle childhood teachers for many years, I was very interested in this opportunity. This talk will focus on the experiences that took place during my week long workshop in Belize, July 2014. (Received September 15, 2014)

1106-97-1865 **Yun Lu*** (lu@kutztown.edu), Mathematics Department, Kutztown University of PA, Kutztown, PA 19530. *Successes and Challenges in Teaching Calculus.*

During this talk, I plan to share the successes and challenges I received while I teach calculus in my school. I will talk about the challenges I have faced, some strategies I have tried, and success and/or failures I received. I will share with my audience students' feedback if time allows. (Received September 15, 2014)

1106-97-1882 **Hugo Rossi*** (rossi@math.utah.edu), 615 Twelfth Avenue, Salt Lake City, UT 84103. *The Flow of Mathematical Concepts in Grades 6-8.*

Working with Teachers and Math Specialists in the School Districts on the preparation of class materials for grades 7-8, one can learn about the structure of the the development of concepts in the CCSS. The three main strands developed in these grades in an intuitive way are Functions, Transformational Geometry, Statistical Thinking. For middle school teachers, these topics are new and the development often surprising. Exploring how to transform the standards into curriculum, and that curriculum into classroom learning has been a difficult, interesting and rewarding experience for all of us. I plan to give a survey of several topics that enriched our meta-understanding of mathematics. (Received September 15, 2014)

1106-97-1957 **Brian Conrey*** (`conrey@aimath.org`). *Mathematics Departments hosting MTCs.* Preliminary report.

There are more than 70 Math Teachers' Circles (MTCs) around the country. Some are hosted by Mathematics Departments who supply space, faculty, and a small amount of financial and staff support. We will argue that this is a viable model for a long term sustainable MTC with synergistic effects for everyone involved. (Received September 15, 2014)

1106-97-2008 **Bob Klein*** (`kleinr@ohio.edu`), Department of Mathematics, 321 Morton Hall, Athens, OH 45701. *Baa Hozho': The Navajo Nation Math Circle Project.*

The Navajo Nation Math Circle Project was started in 2012 by Tatiana Shubin (SJSU) and Henry Fowler (Dine' College) and had as a goal to bring more students and teachers into greater participation in problem solving. The program consists of a two-week summer immersion program for students and teacher professional development. It is the only math circle (we know of) that integrates native culture as a significant portion of the Math Circle. This past summer, 30 students and 25 teachers engaged with mathematics professionals from around the country in great problems.

Klein will report on past activity including some sample problems and descriptions of the cultural activities. Pictures of the activities and the setting for the work will complement the presentation. Klein will also detail future activity and opportunities for the involvement of the mathematics community more broadly. Future work includes the generation of scripts for K-12 teachers to be able to engage students in good problems, and the establishment of a Higher Education-to-K12 mentoring program that would help facilitate Navajo K-12 students connecting with native students enrolled in post-secondary programs. (Received September 15, 2014)

1106-97-2044 **Victor Kostyuk*** (`victor.kostyuk@reasoningmind.org`) and **Nathaniel Rounds**. *Implementing a full curriculum in blended learning: A K12 Case Study.*

It's not easy to design a truly effective mathematical game, instructional video, or problem bank targeting a particular concept or topic. Most current efforts at online instruction focus on one of these methods to supplement in-class learning. A more promising (and challenging) approach is to fully integrate a complete, mathematically rich online curriculum with classroom teaching. In this talk we describe the experience of Reasoning Mind, a Texas-based nonprofit, at working with mathematicians and expert teachers to develop online mathematics curricula, training classroom teachers to understand and complement it in their work with students, implementing at scale, and measuring the effects on students' understanding of and attitudes toward mathematics. (Received September 15, 2014)

1106-97-2046 **Matthew Smedberg*** (`matthew.smedberg@reasoningmind.org`). *A class of one: preparing teachers to make the most of a blended learning environment.*

Teachers in a traditional classroom have to juggle many competing goals and responsibilities. In contrast, teachers in a blended classroom may often automate some components of instruction. This frees the teacher to focus more on the emergent needs of individual students. Unfortunately, teacher preparation often focuses on content knowledge and working with an entire class, so when implementing a blended environment one must prepare teachers for this different role. In this talk, we will discuss some strategies taught to teachers implementing Reasoning Mind, a blended primary-grades mathematics curriculum. We also discuss how the use of these strategies allows the teacher to drive a fully individualized learning path for every student. (Received September 15, 2014)

1106-97-2171 **James R. Valles, Jr.*** (`jrvalles@pvamu.edu`), Department of Mathematics, Prairie View A&M University, P. O. Box 519 – Mailstop 2225, Prairie View, TX 77446-0519. *Creating Student Engagement.* Preliminary report.

In math courses, the dominance of lectures is well-known, and this presents a conundrum for students in that they are not in as much control of their learning as would be optimal. Students should be led to develop their own learning management through such actions as setting their own goals, learning perseverance in mathematical tasks, and developing and maintaining an interest in mathematics.

In this presentation, the author will discuss attempts to motivate students in enhancing their own mathematical engagement. Successes as well as endeavors which were not successful will be discussed as will thoughts on improving and adjusting these endeavors. (Received September 16, 2014)

1106-97-2206 **Emina Alibegovic*** (emina@math.utah.edu), Department of Mathematics, 1400 East 155 South, JWB233, Salt Lake City, UT 84112-0090. *Content courses and practice based teacher education.*

In recent years, several texts (eg Usiskin, Bremigan) have been published which are aimed exclusively at secondary school teachers, and developing deep understanding of mathematics they are required to teach. While these texts attend to developing specialized content knowledge of pre-service mathematics teachers, it is also important to attend to the culture of the classroom, disposition of students, and their habits of mind while also attending to the common content knowledge and development of their skills as mathematicians. We will speak about the collaborative work of several universities on creating courses which are to develop mathematical knowledge for teaching through practice based teacher education. We will provide illustrations from a geometry and a modelling course. (Received September 16, 2014)

1106-97-2213 **Sergey Bereg*** (besp@utdallas.edu), 800 West Campbell Road, Richardson, TX 75080. *Teaching mathematics to computer science students.*

Many courses in Computer Science curricula require mathematics and some sources rely heavily on mathematics (both undergraduate and graduate courses). Teaching mathematics to students with major in non-mathematics could be challenging. In my talk I will share my experience. CS students especially undergraduate students concern about motivation of mathematical concepts. One possible solution of this problem is to involve computational approach, for example, real life computational problems. I find it interesting to see how the student opinion is changing and their grasp of mathematical concepts is improving with this approach. It is not always easy to implement such an approach as it requires extra time in class and additional preparation. This approach has benefits for teaching undergraduate class. However, teaching graduate classes relying on mathematics, for example Computational Geometry course, may benefit from a different approach. The algorithms in these courses already involve some mathematics, especially the proofs. It is important to emphasize how mathematics can help not only in analysis of algorithms but also in their development. (Received September 17, 2014)

1106-97-2220 **Cody L Patterson*** (cpatterson@math.arizona.edu), Department of Mathematics, 617 N Santa Rita Avenue, PO Box 210089, Tucson, AZ 85721. *Can meaning create coherence? The case of a math course for inservice secondary teachers.*

Student success in high school mathematics (and subsequently in college mathematics) depends not only on mastery of mathematical skills and procedures, but also on the ability to deploy these skills strategically and appropriately when one is faced with an unfamiliar problem. In order to use mathematical procedures strategically in novel situations, students must understand what these procedures mean and what they are intended to do. Accordingly, teachers must have a clear understanding of the meanings of mathematical concepts and procedures so that they can convey these meanings to students.

Project ASPIRE has developed an instrument that assesses the meanings with which secondary teachers operate when they teach. Inspired by results from this instrument, we have created a mathematics course for inservice secondary teachers that develops meanings of key mathematical concepts, and then uses these meanings to draw connections among ideas and problems commonly found in the high school curriculum. We will present some sample tasks from this course and discuss the challenges inherent in attempting to build coherence in high school mathematics curriculum and instruction. (Received September 16, 2014)

1106-97-2288 **Yvonne Lai*** (yvonnexlai@unl.edu), **Mary Alice Carlson** (mary.carlson5@montana.edu) and **Ruth Heaton** (rheaton1@unl.edu). *From here, to there, to everywhere: Connecting mathematical time scales to improve teacher education.* Preliminary report.

In helping another learn mathematics, teachers may launch inquiry from as ordinary of an idea as "$4 - 3$ is 1", with children as equal conversation partners. In seconds, teachers must see paths to mathematics of the next moments, days, months, years, and lifetime. In short, teachers must understand how mathematics coheres across many time scales, and how coherence and incoherence may impact teaching. Understanding one step of a mathematics problem may present different challenges than connecting several problems to a larger mathematical idea; and indeed these recurrent mathematical situations may imply different challenges to how we design and use mathematics tasks in teaching and teacher education. We report on an ongoing study of teaching that uncovers the challenges and interactions of mathematics at different scales; we will discuss implications for teacher education. We will present examples of tasks targeting and connecting mathematics at different scales, as well as propose directions for future work based on analysis of existing pools of items assessing mathematical knowledge for teaching. Our findings are relevant to teaching and teacher education at elementary, middle, secondary, and undergraduate levels and beyond. (Received September 16, 2014)

1106-97-2302 **Qingxia Li*** (qli@fisk.edu), 411 Annex Ave, Apt B4, Nashville, TN 37209. *Challenges and Successes in Teaching Developmental Math Courses at HBCUs.*

This research project is supported by NSF Implementation Award(HRD-1332284) at Fisk University. Fisk University is a historically black university and ranks "#1 in Liberal Arts HBCU in research". One of the objectives of this award is to shorten the completion time for math prerequisites and improve mastery of math skills. In Fall 2014, we did a pilot study to assess gains in math content and changes in students' attitude towards mathematics by comparing traditional teaching with teaching with case studies. In this presentation, I will first discuss about the success and challenges in teaching developmental mathematics courses at Fisk University. Then I will demonstrate the changes in math content and attitude towards mathematics collected from the pilot study of 125 students in Intermediate Algebra at Fisk University. (Received September 16, 2014)

1106-97-2318 **Rahman Tashakkori*** (rt@cs.appstate.edu), Dept. of Computer Science, 525 Rivers Street, Boone, NC 28608, and **Robert Mitchell Parry** (rmp@cs.appstate.edu), Dept. of Computer Science, 525 Rivers Street, Boone, NC 28608. *Computer Science Applications for Learning K9-12 Math Concepts.*

The Department of Computer Science at Appalachian State University offers a NSF supported Research Experience for Teachers (RET) summer program in Data Analysis & Mining, Visualization, and Image Processing. The goal of the program is to expose the participants to application of CS in Math and Science and provide them an opportunity to conduct research and develop course modules that can be inserted in their curriculum. This presentation will provide the participants an opportunity to learn about the RET program and the repository of course modules created to teach different mathematics concepts. The course modules utilize basic Scratch or NetLogo programming or image processing and visualization techniques to introduce mathematics concepts. (Received September 16, 2014)

1106-97-2404 **Jason A Aubrey*** (jaubrey@math.arizona.edu), Department of Mathematics, 617 N. Santa Rita Ave., Tucson, AZ 85721. *Developing connection, coherence and creative content for online CCSSM professional development.* Preliminary report.

There is substantial demand for professional development targeting the Common Core State Standards. This presentation focuses on the unique challenges of providing meaningful, engaging online professional development. We will discuss those challenges and showcase tools and tasks developed for an online, masters level professional development course targeted at in-service teachers and focused on algebraic thinking in grades 5-8. (Received September 16, 2014)

1106-97-2520 **Girija s Nair-Hart*** (nairhaga@uc.edu), 3585, Applewood drive, Amelia, OH 45102. *Ed the Imaginary Kid and the Case of a Missing Point.*

Once the stress of test grades are removed from the picture, students seemed to be interested in the discovery of mathematical truth. Providing interactive opportunities through classroom activities that are to be undertaken as a collaborative effort seemed to help students enjoy mathematics as a fun activity. During this presentation I will share three such activities that were well received by introductory algebra, college algebra, and calculus 1 students. After these activities low achieving calculus students performed exceptionally well on a test that was given in a paper and pencil problem solving interview format. The calculus activity to be presented: finite versus infinite limit – the case of a missing point is intended to help students master the concepts of finite and infinite limits and understand the differences and similarities from a numeric and graphical perspectives which later was assimilated into the intuitive and abstract notions of these concepts. The college algebra activity shared during the presentation involves the concept of domain and range of composite functions while the pre-algebra activity of taking the even and odd powers of negative integers resulted in a poem describing the life of Ed the imaginary kid. (Received September 16, 2014)

1106-97-2626 **Nathaniel Rounds***, nathaniel.rounds@reasoningmind.org. *No Coherence without Rigor.* Preliminary report.

It is a truth universally acknowledged that math curricula should coherent, focused, and rigorous. Yet there is not perfect agreement about what these (buzz) words mean. Some of us, especially math educators, use "rigor" to mean "difficulty". Others, especially mathematicians, use "rigor" to mean "mathematically correct". We give some examples of what it might mean for a K-12 math curriculum to be rigorous in the mathematician's sense.

We will argue that mathematically rigorous curriculum can be both appropriately rigorous – in the educator's sense – and achieve the Common Core promise of coherence. (Received September 16, 2014)

1106-97-2629 **Joni J Schneider*** (js1824@txstate.edu), 1230 N. LBJ Dr. 712, San Marcos, TX 78666. *Talk Math 2 Me: A Seminar for Students by Students.* Preliminary report.

In this presentation, we will share how a seminar program, Talk Math 2 Me, was developed and how it is changing the culture of mathematics for undergraduate students. Talk Math 2 Me is a weekly seminar that provides students with the opportunity to present research of mathematics, mathematics history, and/or interesting math ideas to an audience of their peers. The seminar is set in a casual environment for students to share how they view mathematics. This is great way for students to practice speaking in front of an audience, which is a vital skill in any field. This seminar has also been increasing undergraduate students' awareness about how fun and rewarding mathematics research can be. (Received September 16, 2014)

1106-97-2656 **Guadalupe I Lozano*** (guada@math.arizona.edu). *Focus and coherence at the high school level: what they mean, and how to strive for them in the context of specific function and statistics tasks.* Preliminary report.

The CCSSM stemmed, in part, from a vision of coherence and focus for K-12 education in the US. Coherence, the purposeful evolution from particulars to more general structural essentials, and focus, an emphasis on depth over width of curricular content, suggest two different guiding principles in the K-8 standards.

At the high school level, however, the dimensions of focus and coherence seem to overlap. In grades 9-12, we gain depth and loose curricular 'width' (we 'focus') by elucidating conceptual connections that cause previously disconnected ideas to coalesce into one. The Pythagorean identity and the distance formula, for example, may be thought of as conceptually identical, yet are often remembered as disconnected knowledge pieces. From this perspective, coherence at the high school level is achieved through focus, and focus, through coherence.

In this talk, I illustrate how the standards' focus and coherence dimensions may be purposefully thought about (and practically leveraged) in each of several high school level tasks from the function and statistics domains. The presentation borrows from materials I developed for teacher PD sessions on CCSSM Focus, and aims to generate discussion about the interplay between focus and coherence in the high school grade band. (Received September 16, 2014)

1106-97-2735 **J. Maurice Rojas*** (rojas@math.tamu.edu), Texas A&M University, TAMU 3368, College Station, TX 77843-3368. *Some observations on teaching algebraic geometry for undergraduates.*

This is a NON-technical talk on some experiences I've had teaching REUs in algebraic geometry at Texas A&M during 11 summers. I encourage dialogue and questions from the audience, as there is much we can learn from each other's undergraduate teaching experiences. (Received September 16, 2014)

1106-97-2783 **Rhonda D Ellis*** (rdellis@nsu.edu), Norfolk State Univeristy, Department of Mathematics, 700 Park Ave, Norfolk, VA 23504. *Breaking the Mind Forged Manacles in Mathematics.*

Each semester, mathematics educators are presented with students who, in spite of course enrollment, lack requisite fundamentals. Mathematics, a discipline which builds on the absorption of prior concepts, is unlikely to be mastered when proficiency levels in precedent topics are low. Many institutions provide means to mitigate this state of affairs via tutoring services and liberal office hours. Unfortunately, these recourses are scarcely utilized by the students who need them most. As with any skill that is to be mastered, frequent practice and review are required. Instructors may observe reluctance by students to even attempt work outside of the classroom. Why is this? Often, in the case of mathematics, students have a mental block. Such blocks have been created and fostered over many years with students proclaiming, "I'm not good at math." Too often, these assertions go unchallenged by authority figures. In this talk we will discuss some of these issues while exploring strategies and best practices that have proven effective in actively engaging students allowing them to ultimately emerge successfully from the course. (Received September 16, 2014)

1106-97-2841 **James A. Mendoza Epperson*** (epperson@uta.edu), Department of Mathematics, Box 19408, The University of Texas at Arlington, Arlington, TX 76019. *Engaging Preservice and Inservice Secondary Mathematics Teachers in Backmapping Essential Understandings in Calculus to School Algebra.*

Preservice and inservice secondary mathematics teachers often do not have adequate experiences in their undergraduate studies or professional development to make explicit connections between foundational conceptual and procedural knowledge needed for success in calculus and the mathematics taught in school algebra. They also encounter few opportunities to explore the problem solving strides that students must make to be successful in calculus. In this talk, we highlight tasks from a specialized undergraduate mathematics course for preservice secondary mathematics teachers and a graduate course for inservice secondary mathematics teachers that focus on uncovering meaningful connections to school mathematics. We also discuss ways to bridge connections and promote mathematical practices that enable preservice and inservice secondary mathematics teachers to reflect on the essential meanings in calculus that can be backmapped to topics in school algebra. (Received September 16, 2014)

1106-97-2866 **Imre Tuba*** (tubai@slu.edu), Dept of Mathematics and Computer Science, Saint Louis University, 220 N Grand Blvd, St. Louis, MO 63103, and **Gregorio A Ponce** (gponce@mail.sdsu.edu), San Diego State University, Imperial Valley, 720 Heber Ave, Calexico, CA. *Synthesizing pedagogical strategies to teach solving linear equations.*

One of the challenges in middle school mathematics teaching is solving linear equations. This is the beginning of an important and for many students difficult transition from arithmetic with concrete numbers to algebra with symbols, which takes years to complete and is a crucial element of college readiness. Many approaches have been tried to teaching equations. We propose yet another, which we have used with measurable success in professional development for middle school teachers. It synthesizes several strategies from the educational literature and relates solving simple linear equations in one variable to backtracking one's steps, an activity that students are already familiar with. We also discuss how this teaching strategy can lay the foundation to understanding challenging higher level concepts, such as inverse functions, and inverse elements in groups. (Received September 16, 2014)

1106-97-2869 **Paul E Seeburger*** (pseeburger@monroecc.edu), 1000 E. Henrietta Rd., Rochester, NY 14623. *Visually Verifying Homework Problems in Multivariable Calculus.*

Multivariable Calculus involves many concepts that require three-dimensional visualization to fully understand. Using CalcPlot3D, an online applet, students can view & print visual verifications for a variety of multivariable calculus homework problems. Examples include the plane determined by three points, the intersection of two surfaces, contour plots, directional derivatives, tangent planes, level surfaces, Lagrange multiplier optimization, and Riemann sums of rectangular prisms. Short video lessons using CalcPlot3D to visually verify examples of many of these topics can be found on YouTube, and four assessment/exploration activities have been created to help students "play" with the 3D concepts themselves, and to assess improvements in geometric understanding gained from these activities. This paper was published in Loci Resources, an online journal of the MAA. CalcPlot3D is part of an NSF-funded grant project called Dynamic Visualization Tools for Multivariable Calculus (DUE- CCLI #0736968). See http://web.monroecc.edu/calcNSF/. (Received September 16, 2014)

1106-97-2899 **Mark Hoover*** (mhoover@umich.edu), University of Michigan, 610 E. University, Ann Arbor, MI 48104. *Building intercommunity collaborative capacity for preparing mathematics teachers to enact mathematical coherence.*

The purpose of the overall session is to illuminate opportunities for building coherence into the curriculum and instruction afforded by the CCSSM, curriculum materials, progression documents, assessments, and so forth. Coherence is shaped by such supports, but teachers are the lynchpin to actual mathematical coherence as it plays out in instruction. Of course, the mathematical education of teachers is key, but improved mathematical preparation of teachers is a knotty problem requiring expertise that draws from distinct professional communities. In this talk, we argue that there is a need to build intercommunity collaborative capacity to address fundamental needs in the preparation of mathematics teachers. Such collaboration requires tools and norms to help structure cross-professional work. We think that collaboration on item and instructional task development can provide a fruitful educative context for mathematicians and educators to develop MKT and learn to collaborate on MKT. We elaborate how the design of items and tasks integrates knowledge and reasoning in mathematics with instructional practice in ways that productively structure collaboration and we propose item and task development activities designed to build much needed intercommunity collaborative capacity. (Received September 17, 2014)

1106-97-2931 **Glenn Stevens*** (ghs@math.bu.edu). *Empiricism as unifying theme in the Standards for Mathematical Practice.*

In the early 20th century, E. H. Moore, who is often referred to as the father of American mathematics, accepted a challenge from his colleague, John Dewey, to work out "the real correlation of mathematics with science" and thus introduced his famous laboratory method into the teaching of mathematics. While this experiment was eventually abandoned, the underlying ideas that E. H. Moore introduced continue to be influential in American mathematics via the work of his students, R. L. Moore and A. E. Ross, among others.

Focus on Mathematics (FoM) is a collaboration of mathematicians with teachers that is the centerpiece of a community of mathematical practice that has been evolving for over two decades. Central to the FoM approach is the dictum "Experience First" and its corollary "Experience before Formality" both of which elaborate Moore's laboratory method.

In this talk we will discuss the "Experience First" principles and consider ways in which these principles can be used to lend coherence to the Standards for Mathematical Practice, as well as the Content Standards. The ideas will be illustrated with concrete examples of mathematical activities that have been used successfully in our work with teachers in the *Focus on Mathematics* community. (Received September 17, 2014)

Table of Contents for MAA Abstracts of Invited Addresses, Presentations by Teaching Award Winners, SIGMAA Guest Lecturers, and Session Papers

The presenter of each talk is indicated by an asterisk (*) in the abstract.

MAA ABSTRACTS

MAA Invited Addresses, Presentations by Teaching Award Winners, and SIGMAA Guest Lecturers

1106-A0-9 **Robert L. Devaney***, Boston University, Boston, MA. *Cantor and Sierpinski, Julia and Fatou: Crazy topology in complex dynamics.*

In this talk we shall describe some of the rich topological structures that arise as Julis sets of certain complex functions including the exponential and rational maps. These objects include Cantor bouquets, indecomposable continua, and Sierpinski curves. (Received April 27, 2014)

1106-A0-10 **Catherine O'Neil***, Johnson Research Labs, New York, NY 10010. *Making the case for data journalism.*

These days, mathematical models are being deployed for use on the public in all sorts of ways: in politics, in policing, in teacher assessment, in student learning settings, to get jobs, to get insurance, and to get parole. Many of the models have high impact and little review. It is therefore increasingly falling on journalists to understand and scrutinize them for side-effects and false promises. I will explain how this young field is approaching such questions. (Received April 27, 2014)

1106-A0-11 **Christiane Rousseau***, Université de Montréal, Montréal, Canada. *Divergent series and differential equations: past, present, future...*

Divergent series have been successfully used in mathematics for centuries and have occupied an important place in mathematics until the middle of the 19th century. Then, the call for rigor banished them from most of mathematics. In the 20th century, the use of divergent series was justified rigorously in several contexts including differential equations, together with explanations why they are so powerful both in theoretical studies and practical applications. Yet, divergent series remain a relatively marginal subject in contemporary mathematics. In this lecture I will discuss the use of divergent series in differential equations. I will start with some history, and then show how to justify rigorously the use of divergent series. I will also explain why they are not so marginal in the subject. This will bring me to the future... (Received April 27, 2014)

1106-A0-12 **Ken Ono***, Emory University, Atlanta, GA 30332. *Golden numbers and identities: The legacy of Rogers and Ramanujan.*

The "golden ratio" is one of the most intriguing constants in mathematics. It has a beautiful description in terms of a continued fraction. In his first letter to G. H. Hardy, Ramanujan hinted at a theory of continued fractions, which greatly expands on this classical observation. He offered striking evaluations which Hardy described as... "These formulas defeated me completely...they could only be written down by a mathematician of the highest class. They must be true because no one would have the imagination to invent them". G. H. Hardy Ramanujan had a secret device, two power series identities which were independently discovered previously by Rogers. The two Rogers-Ramanujan identities are now ubiquitous in mathematics. It turns out that these identities and Ramanujan's theory of evaluations are hints of a much larger theory. In joint work with Michael Griffin and Ole Warnaar, the speaker has discovered a rich framework of Rogers-Ramanujan identities, one that comes equipped with a beautiful theory of algebraic numbers. The story blends the theory of Hall-Littlewood polynomials, modular forms, and representation theory.

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1106-A0-13 **George Hart***, Stony Brook University, Stony Brook, NY 11790. *Math is Cool!*
Geometric sculptures, mathematical puzzles, insightful videos, hands-on workshop activities, and the museum of mathematics in NYC are all means to demonstrate that math is a living, creative, joyful subject—i.e., that Math is Cool! George Hart will present and discuss a variety of these works from his creative output, and show you some giant mathematical artworks, 3D printed mathematical models, and original workshop projects. For examples of his work, see http://georgehart.com. (Received April 27, 2014)

1106-A0-15 **Diana L. Thomas***, Montclair State University, Montclair, NJ 07043. *Dispelling obesity myths through mathematical modeling.*
Why do individuals only lose a modest amount of weight after performing regular exercise? Why do people plateau in a few months despite reporting high dietary compliance? Are nationwide obesity interventions responsible for leveling rates of obesity prevalence? Do liquid carbohydrates contribute more to weight gain than solid carbohydrates? There are several prevailing hypothesis formulated to answer these questions that are often vigorously debated in both the scientific and public policy arenas. Many times the formed hypotheses are sensible and seem so reasonable that they become strongly held beliefs even despite existence of experimental evidence demonstrating otherwise. These beliefs impact individual perception, health care advice, governmental health standards, and even experimental research design. Mathematical modeling brings a unique and new clarity to address these very important questions. Using several mathematical analyses I will dispel several of these long-standing and widely accepted beliefs in obesity and weight regulation research. (Received April 28, 2014)

1106-A0-136 **Kyle Myers***, Division of Imaging and Applied Mathematics, Office of Science and Engineering Laboratories, Center for Devices and Radiological Health, US FDA.
Mathematical challenges in the evaluation of medical imaging.
A wide variety of advanced medical imaging systems are under development by academia and industry with a broad range of performance characteristics and intended uses. New methods for supporting image interpretation using computer-aided diagnosis algorithms are also being developed for a broad range of diseases, organs, and imaging modalities. The evaluation of imaging devices and computer-aided diagnosis algorithms presents unique mathematical challenges owing to the large data sets involved and the need to consider the role of the human reader. This talk will discuss these challenges and the role of the FDA's Center for Devices and Radiological Health's imaging research program in bringing new medical imaging technologies to U.S. patients. (Received July 28, 2014)

1106-A0-137 **Jim Cushing***, University of Arizona. *Can Cannibalism Save the Day? Dynamic Models for Adaptive Life History Strategies in Response to Climate Change.*
Changing environments generally induce changes in a species' life history traits as it struggles to survive. Traits related to reproduction, survival, and so on can all be affected in various ways that involve complex trade-offs. Cannibalism functions as a natural behavioral trait in a wide variety of animals, including protozoans, invertebrates, and all major vertebrate classes. For example, the interdisciplinary team with which I collaborate has recently documented a strong correlation between cannibalism and climate change (mean sea surface temperature) in colonies of marine seabirds (the Glaucous-winged Gull) on Protection Island WA, a wildlife refuge managed by the US Fish & Wildlife Service. Other traits, such as reproductive synchrony within the colony, have also shown similar correlations. Motivated by these observations, we ask: what are the long term consequences of such changes? Are they adaptive in the long run or simply desperate aberrations of a doomed species? I will describe some mathematical models designed to address these questions. The mathematical backdrop is that of nonlinear, discrete time dynamical systems defined by projection matrices, a fundamental bifurcation theorem, and backward bifurcations that lead to so-called strong Allee effects. (Received July 28, 2014)

1106-A0-140 **Hadley Wickham***, RStudio and Rice University. *Reactive documents for teaching.*
When writing a static document, you have to anticipate the needs of the rea= der—it's a one-way communication. With reactive documents, a document bec= omes more collaborative; it's created by both the author and the reader. Wi= th a reactive document, you can allow the reader to modify parameters, chan= ge assumptions and generally explore a space of parameters. Currently, the = R community is in the middle of an exciting convergence of tools for develo= ping websites (shiny), making reproducible documents (knitr, rmarkdown) and= visualisation (ggvis) that make it very easy to create reactive documents.= In this talk, I'll show you how easy it is to use R to create compelling r= eactive documents for teaching. (Received July 28, 2014)

1106-A0-141 **William Stein***, University of Washington. *SageMathCloud—Integrated mathematical tools in the cloud.*

I will give you a tour of the SageMathCloud, and show you how to use Sage, R, Octave, Python, Cython, GAP, Macaulay2, Singular, and much more in your web browser, edit LaTeX documents with inverse and forward search and Sage mode, collaboratively edit IPython notebooks, Sage worksheets, and all other document types, write, compile, and run code in most programming languages, and use a command line terminal. I will also discuss the commercial aspects of this project and some technical details of how I implemented it. (Received July 28, 2014)

1106-A0-168 **Ricardo Cortez***, Tulane University, Center for Computational Science, New Orleans, LA. *Advances in Computational Modeling of Microorganism Motility*

Biological fluid flows, like those surrounding moving bacteria and spermatozoa, are generated by viscous forces, which completely dominate inertial effects, so that their dynamics may be modeled as a sequence of steady-state snapshots. Microorganism motility has been an active area of research for the last 60 years motivated by questions like: What are effective= locomotion strategies of microorganisms? How do they interact with the surrounding environment? How do microorganisms combine to create patterns of collective motion? What force-generating mechanisms do the organisms use to propel themselves and to attract nutrients in the fluid? The only way to answer these questions is through a combination of theory, experiments, mathematical modeling and simulation. We will present recent collaborative mathematical work, some of it done with undergraduate students, that sheds light on these biological systems and challenges ahead. (Received August 04, 2014)

1106-A0-171 **Trachette Jackson***, University of Michigan, Department of Mathematics, 530 Church St., Ann Arbor, MI 48109. *Mathematical models of tumor vessel formation and targeted therapies that attack the vascular supply.*

Cancer is the collective name given to an entire class of diseases characterized by rapid, uncontrolled cell growth leading to the formation of tumors. To ensure its continued growth, a tumor must acquire a continuous supply of nutrients and the ability to export metabolic waste. It does this by recruiting new blood vessels from the nearby existing vasculature, a process known as tumor-induced angiogenesis. Angiogenesis provides the necessary blood supply for the growth of solid tumors beyond a few millimeters in diameter. A recent advancement in cancer treatment has been combining traditional chemotherapeutic agents with drugs that interfere with a tumor's ability to stimulate blood vessel formation. In this talk, we explore mathematical models of tumor-induced blood vessel formation and discuss related treatment strategies. (Received August 04, 2014)

1106-A0-2422 **Brian Hopkins*** (`bhopkins@saintpeters.edu`). *Frustrate Your Students and Other Questionable Tips.*

"That's a conjecture" is a phrase my students dread hearing. While we are eager to share our knowledge of mathematics, sometimes learning is better fostered when we are silent (or evasive). It can take notable patience and a good poker face to let students explore what we may consider wrong turns, but the rewards can be great.

An outdoor construction project can perk up a technology class, even if it is not exactly topical. A dose of kinesthetic learning can enliven subsequent classroom work. I will discuss these and other examples of pedagogy that I believe justify the extra time required. There will be some mathematical content. (Received September 16, 2014)

Activities, Demonstrations, and Projects that Enhance the Study of Undergraduate Geometry

1106-A1-101 **Ewelina S. McBroom*** (`emcbroom@semo.edu`), Department of Mathematics, Southeast Missouri State University, One University Plaza, Cape Girardeau, MO 63701. *Geometric Constructions through Paper Folding.*

Patty paper offers an alternative to straightedge-and-compass geometric constructions. Through paper folding, students get to make geometric discoveries faster. In this session, I will present a patty paper activity that involves triangle centers. Participants will fold paper to construct perpendicular bisectors, angle bisectors, altitudes, and medians of a triangle. The activity will conclude with a construction of the Euler line. (Received September 15, 2014)

1106-A1-246 **Ward Heilman*** (wheilman@bridgew.edu). *Jack and the Beanstalk, Flintstone and Color Geometries: Teaching Finite Geometries in a course for Secondary Education Mathematics Students.* Preliminary report.

Students preparing to teach Mathematics in high school often think Euclidean Geometry is Geometry. A fascinating way to introduce them to other geometries is the study of finite geometries. We have collected and designed a sequence of finite geometries including the Fe Fo and Yabba Dabba geometries. Students construct and present models of these axiom sets using whatever symbols or mimes they choose, determine the independence of axioms and eventually compose their own finite geometries. This technique allows students to create and understand the idea of a geometry and is also very effective in transmitting the concepts of model and axiomatic system. (Received August 14, 2014)

1106-A1-961 **Leah R Childers*** (lchilders@benedictine.edu). *Finding Treasure: Exploring Taxicab Geometry through a Game.* Preliminary report.

In a modern geometry course (mainly designed for secondary education majors) I use the game "Taxicab Treasure Hunt" (http://www.learner.org/teacherslab/math/geometry/shape/taxicab/index.html) to introduce students to metrics and a nonEuclidean geometry. Students are asked what properties a distance should have and then are asked to explore the taxicab distance using the treasure hunt game. In this talk I will discuss common misconceptions students have as well as elaborate on student research projects generated by interest in this activity regarding isometries and conics. (Received September 09, 2014)

1106-A1-1254 **Douglas G Burkholder*** (burkholderd@lr.edu), Lenoir-Rhyne University, Hickory, NC 28601. *Completing SET: Using the card game SET to demonstrate how to extend finite affine geometry to finite projective geometry.*

The card game SET is useful for helping students understand points, lines, planes, and hyperplanes in a finite geometry setting. Here we show a simple accessible method for extending this to projective geometry by adding 40 additional cards to the deck. Although these new cards represent points at infinity, the new modified game can be played without treating these new cards as special. Any two cards in the Complete SET uniquely define a line with four cards/points. Any three non-collinear cards uniquely defines a projective plane with 13 cards and 13 lines with any pair of lines intersecting at a point. Any four non-coplanar cards define a hyperplane with 40 cards and 40 planes with each pair of planes intersecting at a line. In the Complete SET, any pair of distinct planes intersect at either a single point or a single line. The author will include sample activities for using Complete SET in the classroom. (Received September 11, 2014)

1106-A1-1743 **Daniel Dobbs*** (ddobbs@huntington.edu), 2303 College Ave, Huntington, IN 46750. *The Ruler Matters.*

We present an in-class activity used in a geometry class at Huntington University. The intended audience of this class is math majors, math-education majors and middle-school math education majors who may not have taken a proofs class. The purpose of this activity is two-fold: to use circles and triangles to lead students to discover the differences between various metrics that can be applied to $\mathbb{R}^n$ and to help students think abstractly about geometry. (Received September 15, 2014)

1106-A1-1839 **Pat Touhey*** (ptouhey@misericordia.edu), Misericordia University, Department of Mathematics, Dallas, PA 18612. *Napoleon's Problem.*

In 1797 General Napoleon Bonaparte presented the following problem to Laplace and Lagrange; Given a circle and its center construct, with compass alone, four points constituting the vertices of an inscribed square. The famous mathematicians failed the test and Laplace is said to have replied, "General, we expected everything of you except lessons in mathematics." We will demonstrate the solution to Napoleon's Problem. (Received September 15, 2014)

1106-A1-1909 **Michael D Hvidsten*** (hvidsten@gac.edu), Department of Mathematics, Gustavus Adolphus College, 800 West College Avenue, Saint Peter, MN 56082. *Transformation Composition - A Concrete, Constructive Approach.*

Students in a college-level geometry class typically learn about geometric transformations by starting with reflections and then defining rotations, translations, and glide reflections as compositions of reflections. These basic transformation have specific, intuitive, behaviors that students have little trouble in understanding. However, more complex compositions, for example rotations composed with translations, are difficult for students to conceptualize. This is unfortunate as these compositions are exactly the ones used in fields such as computer graphics and computer vision to model real-world phenomena. This talk will demonstrate a project that is used in the presenter's geometry class where students construct compositions using geometry software. This "concrete" construction allows students to play with compositions and experience visually the effects of compositions on geometric objects. Students who carry out the work of this project invariably have "aha" moments in the computer lab, where they say things like "I finally get it!" (Received September 15, 2014)

1106-A1-1944 **William E. Fenton*** (wfenton@bellarmine.edu), College of Arts & Sciences, Bellarmine University, 2001 Newburg Road, Louisville, KY 40205. *Mini-Chapters for College Geometry.* Preliminary report.

When I have taught College Geometry, I have often required my students to develop a "mini-chapter" on a topic of their choice. Since many of these students plan to become teachers, this assignment strives to improve their skills at learning independently and at presenting new mathematical material. Further, one goal of the course is for students to be able to use The Geometer's Sketchpad as an exploratory tool, and this assignment gives them an opportunity to demonstrate their progress toward this goal.

Each mini-chapter is expected to include exploratory computer activities, written discussion (with a theorem and its proof), and several homework exercises. This follows the structure of the textbook for the course. This presentation will discuss the assignment and its rationale, and how it has evolved over several years. The rubric will be presented, plus examples of student projects. It will conclude with my perceptions of the successes and challenges, and some student feedback. (Received September 15, 2014)

1106-A1-2156 **Peiyi Zhao*** (pzhao@stcloudstate.edu). *Locus problems and analytic geometry.*

Geometry software such as Geometer's Sketchpad has been very useful in aiding explorations and generating conjectures. Yet the conjectures need to be justified. This project contains two parts: The first part consists of geometric constructions using Geometer's Sketchpad that simulate certain activities, and making conjectures on the outcome of the activities. The second part is about the justification of the conjectures. For each conjecture they make, students are encouraged to think about proofs using any method. But they must submit one proof using the analytic method. This project is used in an undergraduate geometry course that prepares teachers at the secondary level. (Received September 15, 2014)

1106-A1-2244 **Marian F Anton*** (anton@ccsu.edu). *Compass and Ruler Constructions Revisited.* Preliminary report.

We demonstrate how compass and ruler constructions were used as an inquiry based activity in the first week of a geometry course in order to introduce the concepts of algorithmic complexity and axiomatic method in mathematical sciences. We will discuss student reaction and the topics developed from this activity. Also we will show snippets of student reports written by using LaTeX and GeoGebra. (Received September 16, 2014)

1106-A1-2382 **David H Crombecque*** (crombecq@usc.edu), 3620 S.Vermont Avenue, KAP 104, Los Angeles, CA 90089. *Planar Hyperbolic Geometry through Inquiry.*

In this talk, we will describe an undergraduate course on Hyperbolic Geometry in the plane. This course is intended for undergraduate Math Majors who may NOT necessarily have had much practice in and exposure to mathematical proofs. The author has been teaching the class in this current version for 3 years (every fall). The course is taught with a focus on Inquiry. In a first phase, students are encouraged to make their own discoveries and conjectures through activities and problems. In a second phase, the class formalizes the results which are then proved by the students themselves in class and in assignments. A sample of activities and problems from this class will be shared and discussed during this session. (Received September 16, 2014)

1106-A1-2414 **Mark A. Brown*** (mabrown@mnu.edu). *Geometry via Student Proof Presentations.*

In Geometry, as in all branches of mathematics, effective communication is important for a thorough understanding of ideas. Too often, ideas are communicated in a one-sided way in which the instructor tells students how to follow some process. During the last three offerings of a Modern Geometry course (a required course for pre-service math teachers and an elective course for mathematics majors), I have used most of the class time for students to give proof presentations and for the class to discuss and analyze the proofs. In this session I plan to: describe a typical class session, share what I have learned from this experience, show examples of incorrect proofs that led to student learning, provide sample problem sets, and discuss grading strategies. (Received September 16, 2014)

1106-A1-2415 **Josh Thompson*** (joshthom@nmu.edu), Josh Thompson, Department of Mathematics, Northern Michigan University, Marquette, MI 49855. *Wooden you like to play with some Penrose Tiles?* Preliminary report.

In this activity, 150 handmade wooden Penrose tiles will be shared among a medium-sized group of geometry "students" who will investigate the geometry of the tiles and the tilings they create. Angle measure, symmetry and translational and fractal geometry are among the topics to be discussed. Then, the group will work together to create two large Penrose tilings which exhibit perfect 5-fold symmetry. Along the way, the mathematics of Penrose tilings will be discussed and contrasted with more familiar tilings of the plane. (Received September 16, 2014)

1106-A1-2419 **Teresa E. Moore*** (moore@ithaca.edu), Dept. of Mathematics, Ithaca College, 953 Danby Rd., Ithaca, NY 13732, and **L. Christine Kinsey**. *Trisections in the Undergraduate Geometry Classroom.* Preliminary report.

In our Modern Geometry course for junior and senior math majors, we introduce students to trisections. We do this either as in class activities or an out of class project. The topic of trisections allows students to blend physical, technological and theoretical approaches to find geometric solutions in many different media and compare them. Students construct origami, linkage and software solutions. They study the history of the problem, and those doing the project independently explore the connection to Galois theory. We encourage students to create solutions but recognize that most spend their effort understanding solutions previously discovered. Students doing a project present what they have learned to the class and write a short expository paper. When the activities are done in class or as short homework exercises, we have a group discussion about different ways of learning and relate the material to traditional geometry problems. (Received September 16, 2014)

1106-A1-2473 **Andras Bezdek*** (bezdean@auburn.edu), Department of Mathematics and Statistics, Parker Hall, Auburn University, Auburn, AL 36849. *On the use of visual mathematics.*

This is a report on a geometric project which was extended to math education, promoting teaching geometry with the use of 3D models. Together with Bret Smith of the Department of Industrial and Graphic Design, the author introduced and organized an interdisciplinary studio modeling course. So far this course was taught three times. The results of this collaboration include a permanent math exhibit placed in Parker Hall on the campus of Auburn University, three exhibit brochures, various videos and a 2 week long exhibit in a local gallery. The talk will also show those models which are used to supplement our undergraduate geometry courses. (Received September 16, 2014)

1106-A1-2686 **Alice E Petillo*** (alice.petillo@marymount.edu), Marymount University, Mathematics, 2807 N Glebe Road, Arlington, VA 22207. *Mathematics, fractals & fashion design: A student-created fractal sculpture.*

Serendipity: faculty members from fashion design and mathematics have lunch together during the first week of classes. Unexpected: a non-fashion-minded mathematics faculty member recognizes the name of Jhane Barnes as the Designer of the Year for the university's upcoming annual Portfolio in Motion show. Interdisciplinary Learning Opportunity: Students build a Sierpinski tetrahedron sculpture to feature fractals, a key element of Jhane Barnes textile designs. A mathematical art gallery, curated in collaboration with the Fine Arts Department, highlights further connections between mathematics and art.

After learning about surface area and volume in an Applied Geometry class, students constructed the initial stages of the Sierpinski tetrahedron. Students calculated the sum of the edge lengths, surface area and volume at different iterations. These constructed tetrahedrons were then combined to form single fractal tetrahedron which was over 4 feet tall. The fractal sculpture generated a lot of interest from the student body as well as visitors to the university. The presenter will share qualitative data on the impact of the the event, suggestions for building relationships across campus, and the actual process of putting such a sculpture together. (Received September 16, 2014)

1106-A1-2690 **Laura M. Singletary*** (lsingletary@leeuniversity.edu), 1120 North Ocoee Street, Cleveland, TN 37311. *Using a Dynamic Software Program to Develop Geometrical Theorems.*

To help students engage with geometrical concepts in meaningful ways, researchers and educators have recommended the use of dynamic software programs to teach undergraduate geometry. The use of a dynamic software program in a geometry course provides students with a digital environment to test conjectures and to develop the informal understandings necessary for students to derive general conclusions and rigorous proofs. During this interactive presentation, I will share two problems I use with my geometry students. In my class, I use these problems to help my students develop the Midquad Theorem through the use of dynamic software. Using these problems with the dynamic software, students are able to construct accurate and dynamic diagrams. Students are then able to interact with these dynamic diagrams, providing a means for students to deduce general properties and relationships. Research suggests that students' uses of such programs have the potential to improve their understandings of geometric concepts. (Received September 16, 2014)

Best Practices for Teaching the Introductory Statistics Course

1106-A5-26 **Rob Eby*** (jeby@blinn.edu). *Using simulations, data pulled from websites, and student data sharing to enhance understanding of the Central Limit Theorem and to better understand what is meant by a confidence interval.*

Often in an introductory statistics class students view statistics as a collection of magic procedures. In keeping with the GAISE guidelines from the American Statistical Society one important topic for students to understand is the idea of a sampling distribution. However, students are often skeptical when a data set is presented in class they think it is rigged. In the presenter's class, students are given a multi-stage assignment. The first stage is to find a website that is "full of numbers." The numbers from some of the web pages are stripped and each is taken as a population. Then each student draws some samples of two different sizes from the population and computes sample data. The sets of sample data are then analyzed to produce a sampling distribution to help students gain an understanding of how the Central Limit Theorem works. Early in the class the Empirical Rule is covered and it is stressed that 95% of your data is within two standard deviations. This is the foundation to look for patterns and then back solve for the formulas from the Central Limit Theorem. The exercise is repeated for confidence intervals. A similar set of activities is used for proportions. A website with the activities will be provided at the end. (Received April 29, 2014)

1106-A5-227 **Wei Wei*** (wei.wei@metrostate.edu), 700 East 7th Street, Metropolitan State University, Department of Mathematics, St. Paul, MN 55106. *Teaching introductory statistics with candies and chopsticks.* Preliminary report.

In this presentation, I will show three in-class group activities using M&M candies and chopsticks in an introductory statistics course. The goal of these activities is to help students understand the materials and improve their learning experience and learning outcomes. The audience will be engaged in doing the first activity. The first activity is to calculate probabilities under a normal distribution using candies, chopsticks and a stopwatch. Students work in a group, record the time of transferring M&M candies from one container to another using chopsticks, and use their data collected to calculate the probability of transferring a candy with a longer/a shorter time than an individual. The second activity is to generate the sampling distribution of proportions for certain color of candies and calculate the mean and standard deviation of the distribution. The last activity is to perform a Chi-square test using M&M candies. Based on the end-of-term survey, 80.5% of the students liked these activities and 78.1% of the students believed these activities helped them to understand the course materials. A detailed survey results will be presented. (Received August 12, 2014)

1106-A5-232 **Dywayne Allen Nicely*** (nicely@ohio.edu), Ohio University-Chillicothe, 101 University Drive, Chillicothe, OH 45601. *Using Supplemental Instruction in Mathematical Statistics at OUC: The study of how Supplemental Instruction has improved student success in introductory statistics at OUC.*

Many students struggle with an introductory statistics course. So, at OUC we are trying to remedy that with the Supplemental Instruction (SI) program. SI at OUC is used as a series of weekly review sessions offered to students who are taking historically difficult classes. These regularly scheduled free study sessions are conducted outside of the classroom by an SI Leader, an undergraduate student, who has previously performed well in the course and who attends all class lectures to take notes and act as a model for the students who are attending the class at the present time. In this presentation, we will show how the students who had the opportunity to utilize the SI sessions perform better than those of their peers who did not. Also, we will show how those students who attended SI sessions with greater regularity outperform their classmates who attended SI sessions sporadically or did not attend SI sessions at all. Data to be shown is from the 2012-2013 academic year (non-SI and control group) and the 2013-2014 academic year (SI and experimental group). (Received August 13, 2014)

1106-A5-657 **Dale K Hathaway*** (hathaway@olivet.edu), Olivet Nazarene University, Department of Mathematics, One University Avenue, Bourbonnais, IL 60914. *Analyzing Grade Inflation Data in an Introductory Statistics course.*

In an Introductory Statistics course it is useful to make use of data that has meaning for the students. This helps to draw them into the course because of their connection to the data. While this is often done through a survey administered the first day of class to collect data directly from the students, this talk will present an additional approach that can be used. At most institutions the graduation program lists the student's degree and majors along with any earned graduation honors. These programs are readily available at graduation and do not require special permission to obtain. The average incoming ACT score for freshmen is also typically available. This talk will discuss how this data has been used in class in the areas of chi-square tests, regression and correlation, and even student projects, providing a nice data theme for the course. (Received September 04, 2014)

1106-A5-935 **Joshua B. Wilkerson*** (wilkerson.josh@gmail.com). *From the Classroom to the Community (and Back Again): Stories of Statistics, Significance, and Service.*

This presentation will outline the design, implementation, and evaluation of service-learning based statistics projects in which students partner with non-profit organizations in their local community. These projects synthesize the major concepts of experimental design, data analysis, and statistical inference in the real-world context of community service. Through these projects students integrate their conceptual understanding of statistics with the practical functioning of their local community, ultimately gaining a deeper appreciation for the role statistics plays in the organization and evaluation of service societies. Successful examples and practical resources will be provided. (Received September 14, 2014)

1106-A5-979 **Adam F Childers*** (childers@roanoke.edu), 221 College Lane, Salem, VA 24153. *Motivating the Material: Theme-Based Introductory Statistics.*

My institution offers several sections of introductory statistics that focus on a central theme of the instructor's choice. My section is based on statistics in the sports industry and is consistently filled with students interested in this topic. Letting the students have a choice of theme invests them in the course and makes motivating the content much easier than in a traditional introductory course since they are interested in the focus of inquiry. There are many rich and large data sets we use for the course that are current and compelling to the students. Websites like basketballreference.com make it easy to get customized data sets that can captivate the students. In addition to the data sets we find online, the students also attend college games and collect data to see firsthand how difficult collecting data can be and what information is and is not contained in the data. Other projects have the students trying to develop their own statistics to measure the overall performance of basketball players and determining the risks of sustaining multiple concussions in retired football players. (Received September 09, 2014)

1106-A5-1129 **Elizabeth Brondos Fry*** (fryxx069@umn.edu) and **Joan B. Garfield** (jbg@umn.edu). *What do we know about best practices in teaching the introductory course?*

This paper presents results from a national survey administered during summer and fall 2013. Data were collected using online versions of the Statistics Teaching Inventory (STI), as part of the larger e-ATLAS study funded by the NSF. The survey was taken by 492 instructors across 315 institutions in the United States. Four versions of the survey were given based on self-selected instructional format: (1) face-to-face class with a sole instructor, (2) face-to-face class taught in a lecture/recitation format, (3) online, and (4) hybrid. The survey contains between 63 and 67 items, depending on the version. Overall, results indicate widespread use of technology and many beliefs aligned with reform recommendations, although pedagogical methods tended to be more traditional. Results from the STI will be described and discussed according to what they reveal about pedagogical methods, curricular emphasis, technology use, assessment practices, and beliefs about teaching and learning introductory statistics. (Received September 10, 2014)

1106-A5-1295 **Rachel M Bates*** (rachel.bates@redlandscc.edu), 1300 S. Country Club Road, El Reno, OK 73036. *Student Perspectives of a Non-Traditional Introductory Statistics Course.*

Calls for comprehensive innovative curriculum and pedagogical changes to mathematics courses and introductory statistics courses have been documented within multiple national reports during the last several decades.Although there is a plethora of research on reform based statistics, there has been little research that describes the characteristics of a problem based introductory statistics course at the college level or on how students respond to a more conceptually-based introductory statistics course. This study addressed the deficiency in literature regarding alternative pedagogical practices and problem based learning within undergraduate level statistics courses. A study analyzing the relationship between students and their mathematical perspective benefits future and current educators as well as future higher education students. Understanding student's experiences and interactions with mathematics can offer insight into future curriculum development and pedagogical design. Considerable improvements in mathematics learning will not occur unless we can succeed in transforming the way mathematics is taught. (Received September 11, 2014)

1106-A5-1296 **Lawrence M. Lesser*** (lesser@utep.edu), Mathematical Sciences Dept., 500 W. University Avenue, El Paso, TX 79968, and **Amy E. Wagler**. *Best Practices for Responding to (the Increasing) Cultural and Linguistic Diversity of Introductory Statistics Students: Research, Resources and Recommendations.*

Across the US, introductory statistics courses are taken by an increasingly diverse population of students. (The authors collectively have almost two decades' experience teaching near the US-México border at a university where the large majority of students are Mexican-American.) To help instructors provide more responsive, equitable, and effective instruction, we overview recommendations and resources drawn from recent research, including: our papers in Nov. 2009 and Nov. 2013 issues of Statistics Education Research Journal and the 2011 Joint Statistical Meetings Section on Statistical Education proceedings, and the first author's paper in the 2010 International Conference on Teaching Statistics proceedings. Concrete strategies (e.g., the first author's paper in the Spring 2011 Statistics Teacher Network) and tools will be shared for teaching and creating curriculum materials in introductory statistics that is more linguistically accessible (not just for English learners, but for all learners!). As time permits, we also briefly share examples of content vehicles and pedagogical strategies that can be more relevant or responsive to diverse cultures. (Received September 11, 2014)

1106-A5-1362 **Dianna J. Spence*** (djspence@ung.edu), University of North Georgia, Department of Mathematics, 82 College Circle, Dahlonega, GA 30597, and **Brad Bailey**. *Enhancing the Benefits of Discovery Projects in Elementary Statistics.* Preliminary report.

We review the distinguishing features of highly student-centered discovery projects, in which students actively design and carry out a statistical investigation in the context of a real-world application of their own choosing. We then describe studies in which the use of such projects has been examined and their impact on student learning and dispositions evaluated in comparison to courses in which such projects are not used. Quantitative and qualitative analyses address additional factors which may govern the impact of these projects on student outcomes; among these factors are specific characteristics of students, instructors, and implementation details of the projects themselves. Preliminary observations are also shared about how these projects have been modified when conducted in the context of a curriculum that includes randomization-based inference, and how project outcomes were strengthened as a result. (Received September 12, 2014)

1106-A5-1606 **Chris Thron*** (thron@tamuct.edu), Mathematics Department, TAMU-CT, 420 Warrior Hall, Killeen, TX 76549. *Addressing social scientists' misconceptions about hypothesis testing.*

Social science statistics textbooks quite commonly contain misleading or outright false statements about significance level and/or p-value. Apparently, mistaken notions are common among social scientists. We show these persistent errors are due vague terminology coupled with lack of understanding of conditional probabilities. We argue that the only way to put a stop to these errors is to change the terminology and increase the emphasis on conditional probability in the social science statistics curriculum. (Received September 14, 2014)

1106-A5-1902 **Paul J Plummer*** (pplummer@ucmo.edu), Dept. of Mathematics & Computer Science, University of Central Missouri, W.C. Morris 222, Warrensburg, MO 64093. *Using Hands on Labs In Basic Statistics to Engage Students and Enhance Learning.*

While there are many technologies available to help visualize statistical concepts and try to capture a student's attention, the power of personal experience and tactile learning for most students should not be lost, as it is essential to their learning process. In this talk I will present some simple lab activities that can be used to engage students in course material and help them grasp key concepts. (Received September 15, 2014)

1106-A5-1911 **Robin Lovgren*** (robin.lovgren@belmont.edu), 1900 Belmont Boulevard, Nashville, TN 37212. *Tying Statistics to the Real World – Group Projects using Linear Regression.*

We introduce the Least-Squares Regression Line early in the semester right after measures of center and spread of the data. The students form groups and choose topics based on their interests. They present several ideas for projects and discuss how each idea might be developed. They research data and narrow their focus to one idea for which they can provide bivariate data. They work through the project in stages through the semester culminating in a final group PowerPoint presentation. This is done with detailed and progressive instruction and with a rubric designed to guide the students' research while minimizing the time spent grading. The students improve their learning in the area of finding, using, and analyzing real data while also learning teamwork and presentation skills. Top student presenters are invited to present at the university's Science Undergraduate Research Symposium. The project can easily be converted to fit a traditional elementary statistics course, or a linked course. (Received September 15, 2014)

1106-A5-1959 **Yevgeniy V. Galperin*** (egalperin@esu.edu), 200 Prospect St., East Stroudsburg, PA 18301. *Histograms, Percentiles and Contrast Stretching.*

As an off-the-beaten-path example that illustrates an application of percentiles to a real-life problem, we consider contrast stretching - one of the most straightforward methods of enhancing low-contrast images. This approach helps students get insights into properties of histograms and also provides an occasion for a review of linear functions. (Received September 15, 2014)

1106-A5-2029 **Wenyi Lu*** (wlu1@gc.cuny.edu), The Graduate Center, CUNY, 365 Fifth Avenue, New York, NY 10016, and **Lina Wu** (lwu@bmcc.cuny.edu), BMCC, CUNY, 199 Chambers Street, New York, NY 10007. *Design Project-based Activities in Teaching Introductory Business Statistics.*

Teaching statistics as a conventional mathematics course does not work for students interested in careers in finance and accounting. To develop students' problem-solving skills that will be useful and practical in their future careers, the presenter propose a way to make the introductory business statistics course more relevant and appealing, through integrating business-projects based activities in curriculum design. The process of designing these projects will be presented with examples of students work from a pilot course held by presenter in Brooklyn College since fall 2013. (Received September 15, 2014)

1106-A5-2042 **RaKissa D Cribari*** (rakissa.cribari@ucdenver.edu), University of Colorado Denver, Campus Box 170, P.O. Box 173364, Denver, CO 80217-3364. *Creating Critical Thinkers in an Introductory Statistics Course.*

Teaching an introductory statistics course is a great opportunity to develop critical thinking skills in our students. Further, a major objective of such a course should include activities that help students to become more critical consumers of statistical information. One approach to developing these types of critical thinking skills is to provide students with opportunities to look back at what summary statistics and graphical summaries tell them about the sample data. This session will focus on an activity designed to look critically at atypical box and whisker plots and what they tell the reader about the original data set. (Received September 15, 2014)

1106-A5-2066 **Eric Ruggieri*** (eruggier@holycross.edu), College of the Holy Cross, 1 College Street, Worcester, MA 01610. *Statistics in the World Around Us – A Group Project for an Introductory Statistics Course.*

The changing MCAT requirements is creating a new group of students who are now being 'forced' to take a statistics course. Some of these students may not see the connection between statistics and their individual field of study. The main idea of the project is to have groups of 2-3 students select a published journal article on a topic of their choice and then present the results of that article to their classmates. The focus of the presentation and subsequent written summary is on the entirety of the statistical process, from formulating a question to drawing the appropriate conclusions based on the statistical analysis. Through this process, students interact with many effective teaching techniques including using real data, incorporating active learning, emphasizing conceptual understanding rather than memorization, honing communication skills (both written and oral), learning to work as part of a team, and providing constant feedback. The overall goals of the project are not only for students to become more effective communicators of statistics, but also for them to see how statistics can be used outside of the classroom. (Received September 15, 2014)

1106-A5-2270 **Beth L Chance*** (bchance@calpoly.edu) and **Allan J Rossman** (arossman@calpoly.edu). *Current thoughts on the introductory course for math and stat majors.*

Several years ago we proposed a new course aimed at mathematically inclined students, arguing that this course could give students a modern introduction to the discipline of statistics through active learning and genuine data while highlighting the mathematical underpinnings of core statistical concepts. In this presentation we will discuss our current vision of the course, how it was evolved over the last decade, and how it relates to forthcoming recommendations from the MAA and ASA about the statistical education of such students. We will present some example investigations from the course, discuss the use of technology, and review some assessment results (what are students' strengths and weaknesses coming out of this course). (Received September 16, 2014)

1106-A5-2289 **Alexander White*** (aw22@txstate.edu), 601 University Drive, Mathematics Department, San Marcos, TX 78666, and **M. Alejandra Sorto** (sorto@txstate.edu), 601 University Drive, Mathematics Department, San Marcos, TX 78666. *Exploring the quantification of evidence: A Better Fit for Goodness-Of-Fit.*

We will share a series of hands-on tasks designed to engage students in the statistical reasoning underlying the quantification of evidence. We will explain how students can create and justify different scenarios where data provides strong, moderate, or weak evidence against a certain claim. The justifications will move students towards the derivation of the Goodness-Of-Fit test statistic. In addition we will share our implementation experience with introductory statistics students. (Received September 16, 2014)

1106-A5-2388 **Hasan Hamdan*** (hamdanhx@jmu.edu), MSC 1911, Dept of Math and Stat, JMU, Harrisonburg, VA 22807. *Teaching Basic Statistics Summer Course Online.*

In this talk, differences between teaching statistics online and face-to-face are discussed based personal experience. In particular, sharing some of the effective techniques, that were found throughout the years, that helped in creating an interactive online class. Some tips on how to balance convenience with rigor, how to best fulfill the course goals and objectives and how to use diverse assessment tools to evaluate students' performance. (Received September 16, 2014)

1106-A5-2424 **Catherine Case*** (ccase@ufl.edu). *Students' Conceptual Understanding of Inference: Connections between Randomization-Based and Traditional Methods.*

At the recommendation of several prominent statistics educators, most notably George Cobb (2007), randomization-based inference methods have begun to replace or complement traditional inference methods in many introductory statistics courses. To explore whether complementing traditional inference with randomization-based methods aids conceptual understanding of the core logic of inference, task-based interviews were conducted with seven AP Statistics students familiar with both inference methods. During the interviews, students were asked to "think aloud" as they used traditional inference methods (z-tests or t-tests) and simulations (using coins, cards, and computer applets) to estimate p-values and draw conclusions about statistical significance in the context of real research studies. Students were then prompted to compare and contrast the approaches, describing the connections perceived between the two. Analysis of students' written work and verbal explanations suggests that although each method presents its own set of challenges, there are advantages associated with complementing traditional inference with randomization-based methods. This session will present these findings and discuss implications for effective teaching of inference. (Received September 16, 2014)

1106-A5-2485 **Mary R Parker*** (mparker@austincc.edu). *Teaching Statistics with Developmental Mathematics.*

When we teach statistics with more class time and more activities, we find that we can integrate in most of the developmental math that students need and, at the same time, get them into a much better frame of mind about learning the concepts well and deeply. Student outcomes compare favorably with a comparison group of university Elementary Statistics students. Early versions of the activities we use are publicly available, along with detailed instructor notes. Teachers of all elementary statistics courses may find useful material in these. These are the foundation of the Pathways project of the Carnegie Foundation for the Advancement of Teaching and the New Math Pathways project of the Charles A Dana Center. (Received September 16, 2014)

1106-A5-2532 **Samuel A. Cook***, scook@wheelock.edu. *What do students know about the mean and what do we expect that they know?* Preliminary report.

An introductory statistics class is rooted in basic understandings of and inferences about statistical distributions, which both require a rich understanding of mean, standard deviation, standard error, as well as the relationships to the data these measures draw on.

This talk will discuss how much time is spent teaching the concept of the mean in the classroom. Results from a study of students who recently completed an introductory statistics class as well as instructors who recently taught an introductory statistics class will be discussed.

Discussion will revolve around the following: How well do students understand the mean? How well do instructors believe their students understand the mean? How much class time is typically spent discussing the mean as a stand-alone concept? (Received September 16, 2014)

1106-A5-2537 **M. Leigh Lunsford*** (lunsfordml@longwood.edu). *Helping Statistical Concepts "Click" with Students.*

Inspired by USCOTS 2013 and a minicourse I took at MathFest in 2013, I recently started using clickers in my introductory level statistics classes. This talk will concentrate on best practices for using these devices and how they can help you implement the Guidelines for Assessment and Instruction in Statistics Education (GAISE). Be prepared to "click" into action as we demonstrate and discuss ways to include this fun and informative component (for both student and instructor!) in your classes. (Received September 16, 2014)

1106-A5-2543 **Kathryn J Montovan*** (kmontovan@bennington.edu), 1 college drive, Bennington, VT 05201. *Teaching Introductory Statistics through big data projects – reflections from a mathematician's first statistics course.*

Statistics is unlike any other math class in most undergraduate curriculums. Most of the math is buried, unnecessary for the use of statistics, and is often too complex for intro students to understand. But students want to be able to use statistics in their areas of study after only one course. As a mathematician, I struggled with teaching statistics for the first time while attempting to teach a one-semester terminal intro stats course. I wanted to prepare students to perform statistics competently on real data and chose to have my students learn statistical computations in R on big-data and based my course around student-directed individual projects. In this talk, I will discuss my misadventures in teaching statistics last spring, what I learned, and what I am excited to try this spring. (Received September 16, 2014)

1106-A5-2612 **Michael D. Miner*** (jcmhs77@aol.com), 65 Edenbrook Drive, Hampton, VA 23666. *The First Night of Statistics Class (Revisited).*

The majority of the degree programs available to adult learners seeking degrees outside of the traditional college learning environments involve a statistics course that introduces research and statistical methods used in business decision making and analysis. Students are required to use a high degree of critical thinking skills to successfully complete these statistics courses. A key first night class participation exercise that is highly effective and engaging; serves as a catalyst for critical thinking; is an enabler for students to learn and understand course concepts: and breaks down the intense level of statistical anxiety that students come into class with is discussed in this presentation. This presentation will show the effectiveness of collecting data from students on the first night of statistics class and then using this data throughout the class to engage student's critical thinking skills and facilitate the learning and understanding of key statistical concepts presented in the Introduction to Statistics course. (Received September 16, 2014)

1106-A5-2641 **Eleanor S. A. Farrington*** (efarrington@maritime.edu). *Adventures in Teaching Statistics to Energy Systems Engineers.* Preliminary report.

This Fall I volunteered to teach a new course we were offering in Probability and Statistics for Energy Systems Engineering majors. Armed with thoughts from a Project NExT workshop on teaching introductory statistics for mathematicians, I strove to design a class using lots of real data and lots of activities. I'll talk about some of my adventures developing and adapting activities and projects for the course, including looks at what worked and what didn't. An important highlight was bringing in an engineer working in the field of alternative energy and building activities around information and data she brought in. (Received September 16, 2014)

1106-A5-2810 **Soma Roy*** (soroy@calpoly.edu), 1 Grand Avenue, Statistics Department, California Polytechnic State University, San Luis Obispo, CA 93407, and **Beth L Chance** and **Allan J Rossman**. *Using simulation to teach inference about correlation and regression in introductory statistics courses.* Preliminary report.

Advances in technology have given statistics instructors the opportunity to use simulation/randomization extensively in their introductory statistics courses. Often instructors only use simulation-based methods to introduce inference for simpler contexts such as one-proportion inference or two-proportions inference, and then go on to use traditional theory-based methods when teaching topics such as inference about correlation and regression. In this presentation, we will discuss how we use simulation-based methods to teach inference about correlation and regression in our introductory statistics courses, and share examples of student activities. We will demonstrate that this approach can be used not only as a teaching tool but also as an analysis tool. We will also discuss the difference that the choice of simulation strategy (random shuffling versus random sampling) makes to the standard error of the slope statistic, how that affects the p-value, and how we address this issue with our students. (Received September 17, 2014)

1106-A5-2818 **Rodica Cazacu*** (rodica.cazacu@gcsu.edu), Georgia College, Department of Mathematics, CBX 17, Milledgeville, GA 31061, and **George E Cazacu**. *Statistically Significant Attempts at Students' Understanding.*

While teaching the introductory statistics course, knowing that most of our students are not mathematics majors, we focus primarily on showing them why they need statistics at a level higher than just manipulating data. During the years we were teaching statistics courses we tried different approaches on the subject and while some did not give the expected results, some became valuable tools for learning, exploring, and assessing students' understanding. This presentation will show some of these methods and how we use them both in the traditional statistics course and the online statistics course that we developed recently. (Received September 16, 2014)

1106-A5-2821 **Jeremy Orloff*** (jorloff@mit.edu) and **Jonathan Bloom** (jbloom@math.mit.edu). *MIT's new introductory course: from probability to frequentist statistics through Bayesian inference.* Preliminary report.

Over the last three years at MIT we have completely redeveloped the syllabus and pedagogy of our introductory probability and statistics class. This talk will focus on the new syllabus, which we revised with several goals in mind. First, we wanted to unify the course by building a much stronger connection between the probability and statistics portions. Second, we wanted students to come away with a deeper understanding of the meaning of (classical) frequentist statistics, the focus of the traditional course. Third, we wanted to introduce students to Bayesian and computational statistics, central tools in modern data analysis.

Our syllabus makes the learning of Bayesian and frequentist statistics mutually reinforcing. We emphasize that both schools are responses to the lack of an objective prior in Bayes theorem. This view allows students to transition smoothly from purely deductive probability to statistical inference, understood as an art involving practical compromises. Furthermore, students intuitively assign a Bayesian interpretation to frequentist constructs such as p-values and confidence intervals. Through early exposure to Bayesian inference, students are inoculated against such misinterpretations. (Received September 16, 2014)

1106-A5-2825 **Jonathan Bloom*** (jbloom@mit.edu) and **Jeremy Orloff** (jorloff@mit.edu). *MIT's new introductory course: using physical space and technology to flip the classroom.* Preliminary report.

Over the last three years at MIT we have completely redeveloped the syllabus and pedagogy of our introductory probability and statistics class. This talk will focus on the pedagogy, emphasizing what we found most challenging, surprising, and useful as we transitioned from a traditional lecture course to a fully flipped class supported by online technology (MITx).

Among the lessons we learned are the importance of a well-designed physical space for active learning, the high value that students place on close interaction with their teachers and classmates, and ways to use automated online feedback to promote timely student reflection on written homework assignments. These lessons have important implications for universities as they consider moving courses online. (Received September 16, 2014)

Fractal Geometry and Dynamics

1106-AA-497 **William C Abram** (wabram@hillsdale.edu), Dept. of Mathematics and Computer Science, Hillsdale College, Hillsdale,, MI 49252-1205, and **Jeffrey C Lagarias*** (lagarias@umich.edu), Dept. of Mathematics, Univ. of Michigan, 530 Church Street, Ann Arbor, MI 48109-1043. *A totally disconnected thread: some p-adic fractals.*

Starting from a problem of Erdős, we are led to problems of estimating Hausdorff dimensions of sets arising in 3-adic dynamics. Generalizing the question then led to study of p-adic arithmetic operations acting on a class of fractal sets that we call p-adic path set fractals. These operations produce many interesting examples. These examples suggest new unsolved problems. The original motivating problem remains unsolved, too. (Received August 30, 2014)

1106-AA-717 **Nuria Fagella** and **Linda Keen*** (lkeen@gc.cuny.edu), CUNY Graduate Center, Mathematics Program, 365 Fifth Ave, New York, NY 10016. *Shell hyperbolic components of transcendental meromorphic maps.*

In this talk we will be concerned with some one (complex) dimensional slices of parameter spaces of transcendental meromorphic maps. Properties of components of these slices are controlled by the singularities of the functions. Components in which the functions have attracting cycles that attract a critical point are often "Mandelbrot-like" whereas those that attract an asymptotic value are quite different and have a shell-like appearance. In this talk we will describe these *Shell components*. (Received September 05, 2014)

1106-AA-805 **Marjorie Wikler Senechal*** (senechal@smith.edu). *Quasicrystal Myths.*

Folklore holds that quasicrystals are

- quasi-something

- rare
- 3-D Penrose-like tilings
- fractalish
- well-understood

But, 30 years into the quasicrystal revolution, we see that none of this is true. (Received September 07, 2014)

1106-AA-818 **Michel L. Lapidus** (lapidus@math.ucr.edu), 900 Big Springs Road, Department of Mathematics, 231 Surge Building, Riverside, CA 92521, and **Robert G. Niemeyer*** (niemeyer@math.unm.edu), Department of Mathematics & Statistics, 1 University Drive, Albuquerque, NM 87133. *Nontrivial paths of the T-fractal billiard in rational and irrational directions.*

We present our latest results on orbits of the T-fractal billiard table. We survey some known results on the T-fractal billiard before presenting an example of an orbit with an irrational slope that 1) converges to a rational elusive point and 2) does so in a way that is consistent with how a nontrivial path in a rational direction is constructed. (Received September 07, 2014)

1106-AA-830 **Tao Chen** and **Yunping Jiang*** (yunping.jiang@qc.cuny.edu), Department of Mathematics, 65-30 Kissena Blvd, Flushing, NY 11367, and **Linda Keen**. *Bounded Geometry and Characterization of Some Holomorphic Transcendental Dynamical Systems.* Preliminary report.

Thurston started an iteration scheme on the Teichmuller space associated with a post-critically finite topological branched covering of the Riemann sphere. Using this iteration scheme, the characterization of a rational dynamical system can be described topologically and geometrically. In this talk, I will talk about our recent work on the characterization of some holomorphic transcendental dynamical systems following Thurston's iteration scheme and bounded geometry. A topological constrain appears as a new topological invariant. By using this new topological invariant and the bounded geometry, we give a characterization of some holomorphic transcendental dynamical systems. We will also connect the bounded geometry condition and this topological invariant with some topological condition. (Received September 09, 2014)

1106-AA-1055 **Ricardo G Perez-Marco*** (ricardo.perez.marco@gmail.com). *New canonical renormalization for polynomials.*

We present a new renormalization approach for polynomials based on surgery with external rays. This new approach makes sense of the renormalization of polynomials with disconnected Julia sets. We discuss in full this situation that requires new rectification theorems for degenerate conformal structures. (Received September 10, 2014)

1106-AA-1146 **Paul Blanchard*** (paul@bu.edu). *The dynamics of rational functions of the form* $z \mapsto z^n + \frac{\lambda}{z^d}$. Preliminary report.

For more than 10 years, Devaney and numerous coauthors associated with Boston University have studied the dynamics of maps of the form

$$z \mapsto z^n + \frac{\lambda}{z^d}.$$

In this talk, I will discuss a number of my favorite results from these investigations. (Received September 11, 2014)

1106-AA-1665 **Michael F. Barnsley*** (michael.barnsley@anu.edu.au). *Old Wine in Fractal Bottles.*

This presentation will define and describe fractal transformations between self-referential spaces, and show how they can act on familiar objects such as Fourier series, Hausdorff measures, orthogonal polynomials, Laplacians and flows, to yield fractal counterparts, some with useful properties. (Received September 14, 2014)

1106-AA-1674 **Yang Wang*** (yangwang@ust.hk), Department of Mathematics, Hong Kong UNiv. of Science and Technology, Kowloon, Hong Kong. *Self-Similar Subsets of the Cantor Set.*

We study the following question proposed by Mattila in 1998: what are the self-similar subsets of the middle-third Cantor set C? For any non-trivial self-similar subset F of C, we show that any linear generating IFS of F should consist of similitudes with contraction ratios $1/3^n$. Furthermore, we provide a necessary and sufficient condition to characterize all self-similar subsets of C. A very simple criterion is formulated to characterize self-similar subsets of C with equal contraction ratio. A finite algorithm is provided to generate all self-similar subsets of C with pre-given contraction ratios. (Received September 14, 2014)

1106-AA-1809 **Richard Balka** and **Yuval Peres***, 1 Microsoft Way, Redmond, WA 98052. *The largest dimension of sets on which Brownian motion is monotone.*

It is a classical fact that level sets of one-dimensional Brownian motion, as well as the set of record times, have Hausdorff dimension 1/2 a.s. Can we find a larger random set A on which Brownian motion is monotone? Perhaps surprisingly, the answer is obtained by using Kaufmann's dimension doubling theorem for planar Brownian motion. Analogous results for Fractional Brownian motion, deterministic self-affine functions and random walks (obtained in joint work with Omer Angel and Andras Mathe) will also be described. (Received September 15, 2014)

1106-AA-2384 **Scott Sutherland*** (scott@math.sunysb.edu), Department of Mathematics, Stony Brook University, Stony Brook, NY 11794. *On the measure of the Feigenbaum Julia set.* Preliminary report.

We discuss a computer-assisted proof that the Julia set of the limit of period-doubling renormalization in the quadratic family (ie, the Feigenbaum-Coulet-Tresser fixed point) has zero measure.

This is joint work with Artem Dudko. (Received September 16, 2014)

1106-AA-2551 **Nishu Lal*** (lal@oxy.edu), 1600 Campus Rd, Los Angeles, CA 90041, and **Michel L. Lapidus** (lapidus@math.ucr.edu), University of California, Riverside, Riverside, CA 92521. *Spectral Decimation and Complex Dynamics: Laplacians on Self-Similar Fractals and Their Spectral Zeta Functions.*

We discuss the spectral zeta functions of certain self-similar differential operators, such as fractal Sturm-Liouville operators on the half-line and the Laplacian on the unbounded Sierpinski gasket. In the case of the bounded Sierpinski gasket, as was shown by A. Teplyaev, extending the known relation by M. Lapidus for fractal strings, the spectral zeta function of the Laplacian has a factorization formula with respect to the iteration of a rational map on $\mathbb{C}$ which arises from the decimation method. Using the decimation method and its extension to several complex variables by C. Sabot, we obtain an analogous factorization formula of the spectral zeta function, but now expressed in terms of a suitable hyperfunction, a geometric zeta function, and the iteration of a multi-variable rational function acting in complex projective space. This talk is based on joint work with M. Lapidus. (Received September 16, 2014)

1106-AA-2733 **Elizabeth L Fitzgibbon*** (elizabeth.fitzgibbon@salve.edu), Salve Regina University, 100 Ochre Point Ave, Newport, RI 02840. *Complex rational maps and the structure of Julia sets from accessible Mandelbrot sets.*

We observe many small copies of the well-known Mandelbrot set within the parameter space of the family of complex rational maps $z \mapsto z^n + \frac{\lambda}{z^d}$, where λ is a complex parameter and $n = d \geq 2$. An infinite number of these Mandelbrot sets are located around the boundary of the connectedness locus. It is possible to define parameter rays within the Cantor set locus which land on the cusps of these accessible Mandelbrot sets. Maps taken from the main cardioids of these sets have attracting periodic cycles. I will describe a method for constructing models of Julia sets corresponding to these maps. I will then discuss which models are allowable and how these models vary as λ is varied around the boundary of the connectedness locus. (Received September 16, 2014)

1106-AA-2764 **Ivan Sudakov*** (sudakov@math.utah.edu), 155 S 1400 E ROOM 233, Salt Lake City, UT 84112-0090. *Fractal transition in melt ponds and dynamics of the climate system.* Preliminary report.

In this research, we present a standard conceptual climate model – an ordinary differential equation with ice–albedo feedback taking into account the albedo of melt ponds. We modify the model assuming a stochastic distribution of melt pond radii, based on the Fokker-Plank equation. After that we investigate equilibria of the resultant stochastic ODE under the key assumption that the surface temperature is a slow function of time relative to melt pond radius. Different bifurcation regimes were obtained for this model. One of them may be quite interesting for climate applications, where the temperature of this system is stabilized only due to the fractal transition in melt pond geometry. (Received September 16, 2014)

The Mathematics of Rogers and Ramanujan

1106-AB-40 **George E Andrews*** (gea1@psu.edu), Department of Mathematics, Pennsylvania State University, University Park, PA 16802. *The Generalized Rogers-Ramanujan Series and Related Mysteries.*

In 1983, D.M. Bressoud published An Easy Proof of the Rogers-Ramanujan Identities (J. Number Th., 16(1983), 235-241). The true charm of his proof has been noticed by many. The conclusion of the paper is devoted to a generalization of his result where he proves a polynomial identity which in the limit yields two instances of the generalized Rogers-Ramanjuan series/product identity (Proc. Nat. Acad. Sci., 71(1974), 4082-4085). A careful study of this final result in Bressoud's paper provides some surprises, mysteries, and open problems. (Received May 21, 2014)

1106-AB-45 **Bruce C. Berndt*** (berndt@illinois.edu), Dept. of Mathematics, University of Illinois, 1409 W. Green St., Urbana, IL 61801. *A Survey of the Rogers–Ramanujan Continued Fraction.*

The Rogers–Ramanujan continued fraction was first studied by L. J. Rogers in 1894. However, most of our knowledge of this continued fraction is due to S. Ramanujan, and almost all of his work can be found in his earlier notebooks and in his lost notebook. We give a survey of what is known about this fascinating continued fraction. (Received May 23, 2014)

1106-AB-102 **James Lepowsky*** (lepowsky@math.rutgers.edu), Department of Mathematics, Rutgers University, 110 Frelinghuysen Rd., Piscataway, NJ 08854-8019. *Generalized Rogers-Ramanujan identities and vertex operator algebra theory.*

We briefly sketch how an early goal of trying to "understand" the Rogers-Ramanujan identities and generalizations in some representation-theoretic way has led to many developments in vertex operator algebra theory. This program, which began in the late 1970s, remains extremely active today, as the respective theories have dramatically advanced. (Received July 16, 2014)

1106-AB-113 **S. Ole Warnaar*** (o.warnaar@maths.uq.edu.au), School of Mathematics and Physics, The University of Queensland, Brisbane, QLD 4072, Australia. *Hall–Littlewood polynomials and Rogers–Ramanujan identities.*

The Hall–Littlewood polynomials are a one-parameter extension of the famous Schur functions, of importance in representation theory and algebraic combinatorics. In this talk I will describe the role played by the Hall–Littlewood polynomials in recent generalisations of the Rogers–Ramanujan identities to the twisted affine Lie algebra $\mathrm{A}_{2n}^{(2)}$. (Received July 18, 2014)

1106-AB-861 **Michael J. Griffin*** (mjgrif3@emory.edu), Dept. of Math and CS, Emory University, 400 Dowman Dr., W401, Atlanta, GA 30322. *Algebraic units arising from a framework of Rogers–Ramanujan identities.*

The q-series given by the two Rogers–Ramanujan identities

$$\sum_{n=0}^{\infty} \frac{q^{n(n+\sigma)}}{(1-q)\cdots(1-q^n)} = \prod_{n=0}^{\infty} \frac{1}{(1-q^{5n+1+\sigma})(1-q^{5n+4-\sigma})},$$

where $\sigma = 0$ or 1, play many roles in mathematics and physics. The right hand side of the identities show that these q-series are essentially modular functions. Their quotient, the Rogers–Ramanujan continued fraction, has the special property that its *singular values* are algebraic integral units. In recent joint work, the speaker, Ken Ono, and Ole Warnaar have found a framework which extends these identities to doubly-infinite families of q-series identities of the form

"Infinite sum" = "Infinite product modular function".

These new q-series are specialized characters of affine Kac–Moody algebras. As with the Rogers–Ramanujan functions, they have a rich structure of algebraic special values. Here we consider this structure; generalizing the Rogers–Ramanujan continued fraction, we prove in the case of $\mathrm{A}_{2n}^{(2)}$ that the relevant q-series quotients give algebraic integral units. (Received September 08, 2014)

1106-AB-1088 **Amanda Folsom***, Amherst College/Yale University, Mathematics Department, Amherst, MA 01002. *Selberg's q-difference equations, the Rogers-Ramanujan continued fraction, and unit groups.*

In this talk, we will first discuss early work of Selberg, which extends the celebrated Rogers-Ramanujan identities via a general family of q-difference equations. Building from Selberg's work, we will then show how to construct fundamental groups of modular units (one of which is the Rogers-Ramanujan continued fraction) within the modular function fields, as well as unit groups within number fields; in particular we address a problem originally studied by Gauss, Gupta, and Zagier. We will also discuss "radial limits" of the Rogers-Ramanujan functions, in light of recent related work pertaining to Ramanujan's mock theta functions. (Received September 10, 2014)

The Mathematics of Planet Earth

1106-AC-264 **Alik Ismail-Zadeh*** (alik.ismail-zadeh@kit.edu), IEPTMG, Russian Academy of Sciences, Moscow, Russia; also KIT, Karlsruhe, Germany. *Inverse Retrospective Problems in Dynamics of the Earth's Interior.*

The Earth's dynamics (characterized basically by a temperature and flow in the mantle) can be described by mathematical models, i.e., by a set of partial differential equations (e.g., the Stokes equations, the heat balance equation, the equation of state and the rheological law) and boundary and initial conditions defined in a specific domain. Present geophysical and geodetic observations provide a clue to understanding dynamics of the Earth interior in the geological past. Assimilation of present observations allows to constrain the mantle temperature and flow in the past using the dynamical mathematical models. Quantitative tools are required to assimilate the data and hence to solve inverse retrospective problems in geodynamics. The basic inversion methods (the backward advecton, adjoint, and quasi-reversibility techniques) and their applicability to restore the evolution of the Earth interior will be presented and discussed. (Received August 17, 2014)

1106-AC-580 **Todd Arbogast*** (arbogast@ices.utexas.edu), Inst. for Computational Engng. and Sciences, 1 University Station C1200, Austin, TX 78712, and **Marc A Hesse** and **Abraham L Taicher**. *Approximation of a Degenerate Elliptic Equation Arising from a Two-Phase Mixture Modeling the Motion of the Earth's Mantle.*

We consider the linear but degenerate elliptic system of two first order equations $\mathbf{u} = -\phi\nabla p$ and $\nabla\cdot(\phi\mathbf{u}) + \phi p = \phi f$, where the *porosity* $\phi \geq 0$ may be zero on a set of positive measure. The model equation we consider has a similar degeneracy as that arising in the equations describing the mechanical system modeling the dynamics of partially melted materials, e.g., in the Earth's mantle, and the flow of ice sheets, e.g., in the polar ice caps and glaciers. In the context of mixture theory, ϕ represents the phase variable separating the solid one-phase ($\phi = 0$) and fluid-solid two phase ($\phi > 0$) regions. Two main problems arise. First, as ϕ vanishes, one equation is lost. Second, after we extract stability or energy bounds for the solution, we see that the *pressure* p is not controlled outside the support of ϕ. After an appropriate scaling of the pressure, we can show existence and uniqueness of a solution over the entire domain. We then develop a stable mixed finite element method for the problem, and show some numerical results. (Received September 02, 2014)

1106-AC-741 **Pietro-Luciano Buono***, Faculty of Science, 2000 Simcoe Street North, Oshawa, Ontario , Canada. *Patterns in collective motion and space use of animal populations: a mechanistic approach.*

Patterns associated with animal movement are observed at various scales in nature. One can think of the formation of fish schools or flocks of birds which show an amazing level of self-organization and coherence. At the macroscopic scale, the distribution of animal populations also shows patterning driven by behavior, but also by exogenous factors: landscape, land cover, human disturbances, etc. In this talk, I will present recent advances in the mathematical modelling of animal movements and the emerging patterns observed. By a mechanistic approach, one means approximating probability based local rules of movement of a reference individual via a limiting process to a deterministic partial differential equation describing macroscopic features of movement; i.e. patterns. Examples are drawn from models of single species collective motion, models of divided populations, patterns of space use for large mammals (e.g. coyotes, caribou). (Received September 05, 2014)

1106-AC-953 **Clint Dawson*** (clint@ices.utexas.edu), 201 E. 24th St. Stop C0200, University of Texas at Austin, Austin, TX 78712. *Mathematics of the Coastal Ocean.*

In this talk, we will discuss mathematical modeling issues arising in coastal ocean applications. In particular, we will describe different models for wave propagation, and how these models are used for understanding tides, waves, hurricane storm surge, tsunamis, and other phenomena. We will also discuss how these models are solved numerically, and give several examples of how data are used to inform and validate models. (Received September 09, 2014)

1106-AC-1516 **Juliann Leifeld** and **Richard McGehee*** (mcgehee@umn.edu). *Hopf Bifurcation for Discontinuous Vector Fields with Application to an Ocean Box Model.* Preliminary report.

Simple climate models provide a rich supply of mathematically interesting dynamical systems. A classic box model of overturning ocean circulation exhibits a phenomenon leading to a Hopf bifurcation theorem for discontinuous vector fields. (Received September 13, 2014)

1106-AC-1569 **Kenneth M. Golden*** (golden@math.utah.edu), University of Utah, Department of Mathematics, 155 S 1400 E, RM 233, Salt Lake City, UT 84112-0090. *Modeling the Melt: What Math Tells Us About the Shrinking Polar Ice Caps.*

The precipitous loss of Arctic sea ice has far outpaced expert predictions. In this lecture we will explore the mathematical underpinnings of this mystery, and show how we are using the mathematics of multiscale composites and statistical physics to study key sea ice processes. This work is helping to better represent sea ice in climate models, and improve projections of the fate of Earth's ice packs as well as the response of polar ecosystems. We will conclude with a short video from a 2012 Antarctic expedition where sea ice properties were measured. (Received September 14, 2014)

1106-AC-1727 **Mary F Wheeler*** (mfw@ices.utexas.edu), Center for Subsurface Modeling, University of Texas at Austin, 201 East 24th Street, Austin, TX 78712. *Coupling flow and mechanics porous media.*

We discuss coupling of multiphase flow and geomechanics in porous media. Theoretical and computational results are presented for this poroelastic problem. (Received September 15, 2014)

1106-AC-2359 **Edward Belbruno*** (belbruno@princeton.edu). *Lithopanspermia Hypothesis.*

The Lithopanspermia Hypothesis addresses a long standing question on the origin of life on Earth. It proposes that life on Earth started due to biogenic material trapped within meteoroids that crashed into the Earth and was released into the environment. The origin of the meteoroids, or rocks, would be from the surface of planets orbiting other stars within the original cluster of stars that the Sun formed within, and were transferred to the Earth. We provide a solution to the transfer aspect of this hypothesis. Previous studies have shown that the probability of transfer of material from a planet of one star to be captured by another star was very unlikely. In a recent paper published by this speaker, together with A. Moro-Martin, R. Malhotra, and D. Savransky, we show that by using the weak escape mechanism, which is chaotic in nature, the probability of solid material to be captured by another star in the cluster, increases dramatically by a factor on the order of one billion, thereby making the lithopanspermia much more likely and providing a viable transfer mechanism. (Received September 16, 2014)

1106-AC-2677 **Hans G Kaper*** (kaper@mathclimate.org), Department of Mathematics and Statistics, Georgetown University, St. Mary's Hall 338A, Washington, DC 20007, and **Christiane Rousseau** (rousseac@dms.umontreal.ca), Department of mathematics and statistics, University of Montreal, C.P. 6128, succ. Centre-ville, Montreal, Quebec H3C 3J7.
Mathematics of Planet Earth - What is it all about?

"Mathematics of Planet Earth 2013" (MPE2013) and its successor "Mathematics of Planet Earth" (MPE) is a grass-roots organization of mathematical scientists from around the world. Its goal is to learn about the issues facing our planet, to highlight the role our discipline can play in addressing these issues, and to inform the public about the accomplishments to date. In the opening talk of this session, the speakers will give an overview of MPE activities and discuss recent developments and future plans. (Received September 16, 2014)

Mathematics and Voting Theory

1106-AD-374 **Nicolas Lanchier*** (nlanchie@asu.edu), School of Mathematics, Arizona State University, Tempe, AZ 85287. *Consensus and Disagreements in the Axelrod Model for the Dissemination of Culture.*

The Axelrod model is a spatial stochastic model for the dynamics of cultures which includes two important social factors: social influence, the tendency of individuals to become more similar when they interact, and homophily, the tendency of individuals to interact more frequently with individuals who are more similar. Each individual is characterized by a set of cultural features, and pairs of neighbors interact at a rate proportional to the number of features they share, which results in the interacting pair having one more cultural feature in common. This model has been extensively studied during the past ten years based on numerical simulations while there is a lack of analytical results. This talk gives rigorous fluctuation and fixation results for the one-dimensional system that sometimes confirm sometimes refute some of the conjectures formulated by statistical physicists and social scientists. (Received August 26, 2014)

1106-AD-376 **John Cullinan*** (cullinan@bard.edu) and **Sam Hsiao**. *A Borda Count for Partially Ordered Ballots.*

The application of the theory of partially ordered sets to voting systems is an important development in the mathematical theory of elections. Many of the results in this area are on the comparative properties between traditional elections with linearly ordered ballots and those with partially ordered ballots. In this talk we present a scoring procedure, called the partial Borda count, that extends the classic Borda count to allow for arbitrary partially ordered preference rankings. We further characterize the partial Borda count in the context of weighting procedures and in the context of social choice functions, extending Young's 1974 uniqueness theorem. (Received August 26, 2014)

1106-AD-1130 **Catherine Stenson*** (stenson@juniata.edu). *Some Uses of Polytopes and Hyperplane Arrangements in Voting Theory.* Preliminary report.

We survey some of the ways in which polytopes and hyperplane arrangements are used in voting theory. In particular, these objects arise in the context of weighted voting, in which voters may have different numbers of votes (as in the U.S. Electoral College) and a quota must be met to pass a measure. We also present a new polytope whose vertices have a nice interpretation in terms of the Shapley-Shubik power index. (Received September 10, 2014)

1106-AD-2185 **Tomas J. McIntee***, tomas.mcintee@gmail.com, and **Don Saari**. *Finding Geometric Answers to Voting Problems.*

The relationship between pairwise voting criteria and positional voting rules, including but not limited to the Borda count, have been of substantial interest since the eighteenth century. Pairwise voting criteria of historic interest include the Condorcet winner and Condorcet loser criteria, along with the Condorcet paradox. This presentation will discuss some recently developed geometric techniques for discerning the complete relationships between pairwise voting criteria and the outcomes of positional voting rules for $n = 3$ candidates. In addition to providing entirely new answers to centuries-old concerns, these techniques are easily understood and applied. (Received September 16, 2014)

1106-AD-2200 **Michael E. Orrison*** (orrison@hmc.edu). *Basic Algebra of Voting.* Preliminary report.

Voting is something we do in a variety of ways, and the mathematics behind different voting procedures can sometimes seem daunting and disconnected. In this talk, I will discuss how basic ideas from linear algebra, abstract algebra, and representation theory can be used to unify some of the foundational ideas in voting, and how such an approach to voting theory can provide an intriguing yet friendly gateway to the subject. (Received September 16, 2014)

Mathematical Techniques for Signature Discovery

1106-AE-1226 **Jennifer B. Webster*** (jennifer.webster@pnnl.gov), Richland, WA 99352, and **Zoe N. Gastelum** (zoe.gastelum@pnnl.gov), Richalnd, WA 99352. *Mathematical Formulation of "Fuzzy" Problems for Signature Discovery.*

Applying the scientific method to social science problems for the facilitation of machine learning and graph analysis methods can present unexpected challenges to many researchers. As with most interdisciplinary research, translation between the technical approach and the application domain is critical, beginning early in the problem definition, and permeating throughout the research process. Questions like "find me the liars in this data set" are not easily (nor consistently) translated to a "find me the outliers" problem. In addition to interaction between domain purpose and mathematical formulation, there can also be problems related to data such as quality, clarity and domain-specific nuances. In this presentation, we will discuss problems in both mathematical formulation and data with regards to a business intelligence problem – namely, can we identify and characterize procurement networks within a commercial international shipping data set? This will include the definition of a mathematical basis for addressing a business intelligence tasks, identification and development of mathematical tools necessary for working with the problem, the data pre-processing required for these tools to be useful, and the exploratory data analysis required to make all of this possible. (Received September 11, 2014)

1106-AE-1326 **Nathaniel Beagley*** (nathaniel.beagley@jhuapl.edu), 11100 Johns Hopkins Road, Laurel, MD 20723-6099. *The Application of Signature Models to Intelligence, Surveillance, and Reconnaissance Research.*

One area in the field of ISR (Intelligence, Surveillance, and Reconnaissance) research involves combining measurements from sensors along with kinetic models in a Kalman Filter framework to locate, identify, and track targets of interest. The problems spaces can grow quickly in complexity with the use of multiple sensors requiring methods for optimally managing data collection, and with the presence of multiple targets requiring association algorithms to resolve between multiple candidate scenarios.

This talk will describe our efforts to augment this process using signatures, developing and inserting signature models into traditional ISR processes and accurately quantifying the predicted performance change. We are specifically interested in developing signature models that allow high levels of ISR performance to be maintained when tested with environments that cause degraded or missing sensor data. (Received September 12, 2014)

1106-AE-1465 **Mark E. Oxley*** (mark.oxley@afit.edu), Air Force Institute of Technology, 2950 Hobson Way, Bldg 641/ENC, Wright-Patterson AFB, OH 454533-776. *A Mathematical View of Signature Discovery for Classification Systems.*

This talk will discuss the mathematical aspects of signature discovery. The mathematics will at an abstract, basic level so undergraduate student can follow the discussion. We define a signature and discuss the discovery process. We will use a classification problem as a concrete problem to demonstrate the mathematical theory. Other examples will be given. (Received September 13, 2014)

1106-AE-2398 **Lori Beth Ziegelmeier*** (lziegel1@macalester.edu), Macalester College, 1600 Grand Avenue, Saint Paul, MN 55105, and **Chad Topaz** and **Tom Halverson**. *The Topology of Biological Swarms.*

In this talk, we apply methods from topological data analysis (TDA) to analyze the dynamics of biological swarms. We analyze the classical swarming models of Vicsek (1995) and D'Orsonga, Chuang, Bertozzi, Chayes (2006), in which simple local interactions produce aggregate behavior. In these simulations, numerical position and velocity data are viewed as point clouds varying over time. Using methods from persistent homology, we are able to capture topological features, such as connected components and topological circles, that persist at multiple scales. These topological features detect events that classical global metrics do not. (Received September 16, 2014)

1106-AE-2650 **Andrew Stevens***, Pacific Northwest National Laboratory, P.O. Box 999; K7-20, Richland, WA 99352. *Dictionary learning for automatic feature extraction in signature discovery.*

Dictionary learning is a relatively recent development in image analysis based on statistical factor analysis. An introduction to dictionary learning and some extensions will be presented along with how it fits into more recent developments like deep neural networks. The usefulness of dictionary learning for automated feature extraction will be shown by comparison to hand engineered features. Finally, some applications in signature discovery will be discussed. (Received September 16, 2014)

1106-AE-2852 **Elizabeth Jurrus*** (elizabeth.jurrus@pnnl.gov), Scientific Computing and Imaging Institute, University of Utah, 72 S Central Campus Drive, Room 3750, Salt Lake City, UT 84112, and **P. Thomas Fletcher**, **Eleanor Wong**, **Andrew Stevens**, **Yannun Sun** and **Michael S Hughes**. *Intra-Category Image Classification using Texture and Shape Features.*

The computer vision community is experiencing a rapid growth of data from airborne motion imagery and full motion video. The most accurate method for detecting objects of interest in these immense datasets is through human analysis. There exists a significant need for automated methods to help analysts perform accurate, content-based image retrieval in large image datasets. We are developing an algorithm with promising results that classifies bird species based on their combined shape and local image features. Working with natural and segmented bird images, we automatically build a shape model have developed a classification method that identifies birds of different shapes with high accuracy. This is performed by first using dictionary learning to extract natural image features followed by a distance kernel computation on bird segmentations. A relevance vector machine performs classification on the local features and shape distances using pairwise comparisons. This new algorithm is invariant to scale and rotation (objects of interest can be at different angles and sizes), robust to changes in lighting, uses linear low dimensional data representation (representing data in its intrinsic dimensionality), and requires few parameters to tune. (Received September 16, 2014)

Recent Advances in Mathematical Modeling of the Environment and Infectious Diseases

1106-AF-501 **Edward Allen*** (edward.allen@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79363-1042. *Modeling Environmental Variability With Mean-Reverting Processes.*

Environmental variability is often treated by modifying the parameters in a mathematical model. In the present investigation, two common methods to incorporate the effects of environmental variability in stochastic differential equation models are studied. The first approach hypothesizes that the parameter satisfies a mean-reverting stochastic process. The second approach hypothesizes that the parameter is a linear function of Gaussian white noise. The two approaches are discussed and compared analytically and computationally. Properties of several mean-reverting processes are compared with respect to nonnegativity and their asymptotic stationary behavior. The effects of different environmental variability assumptions on population size and persistence time for simple population models are studied and compared. In addition, environmental data are examined for a gold mining stock. It is concluded that mean-reverting processes possess several advantages over linear functions of white noise in modifying parameters for environmental variability. (Received August 31, 2014)

1106-AF-502 **Zhilan Feng*** (fengz@purdue.edu), 150 N. University Street, Department of Mathematics, West Lafayette, IN 47907. *Influence of heterogeneity in model predictions for public health policymaking.* Preliminary report.

Mathematical modeling of infectious diseases has affected disease control policy throughout the developed world. Policy goals vary with disease and setting, but preventing outbreaks is common. We use epidemiological models that incorporate various spatial and temporal heterogeneities to demonstrate how these heterogeneities may influence model predictions, particularly their implications for public health policymaking. (Received August 31, 2014)

1106-AF-1071 **Jim M Cushing*** (cushing@math.arizona.edu), Department of Mathematics, University of Arizona, 617 N Santa Rita, Tucson, AZ 85721, and **Amy Veprauskas** and **Shandelle M Henson**. *Environmental change and life history strategies: cannibalism and reproductive synchrony.* Preliminary report.

Environmental change, such as a reduction in food resources, can significantly alter the life history strategies of individuals in a population. For example, increased cannibalism has been widely documented in a large number of species, across from many taxa, in response to food shortages. In turn, individuals within a population will adapt their life history strategies in various ways in response to increased cannibalism. For example, recent observations made in glaucous-winged gull colonies on Protection Island National Wildlife Refuge have documented strong correlations among food shortages (caused by a rise in mean sea surface temperatures), adult cannibalism of eggs, and reproductive timing (egg laying) of females. We formulate a stage-structured matrix model for a cannibalistic population in order to investigate the complicated dynamics that can result in such a scenario, especially with regard to how different strategies relate to population extinction or persistence. Mathematically, the study involves the stability and bifurcations of equilibria and synchronous periodic cycles and the occurrence of multiple attractors and Allee effects. (Received September 10, 2014)

1106-AF-1443 **Sophia Jang*** (sophia.jang@ttu.edu), Department of Mathematics & Statistics, Lubbock, TX 79409, **James Baglama**, Kingston, RI , and **Li Wu**, Kingston, RI. *Dynamics of phytoplankton-zooplankton systems with toxin producing phytoplankton.*

There has been a global increase in harmful plankton blooms in the last few decades. One group is the toxin producing phytoplankton (TPP), which are the toxin producers that can contaminate seafood or kill higher trophic organisms. In this study, we use models of phytoplankton-zooplankton interactions with periodic toxin releasing by phytoplankton to investigate extinction and persistence of the populations. Models with spatial variations are also incorporated using reaction-diffusion equations. Consistent chaotic behavior is observed in the spatial homogeneous models when the zooplankton mortality and the maximal toxin liberation are not large. Passive diffusion of the plankton populations, however, can eliminate the chaotic interactions. (Received September 13, 2014)

Making the Case for Faculty Relevance: Case Studies in Best Practices for Classroom Teaching

1106-AG-635 **Annalisa Crannell*** (annalisa.crannell@fandm.edu), F&M Mathematics, Box 3003, Lancaster, PA 17604-3003. *Four-and-a-half useful methods for grading mathematical writing.*

During the early 1990's, the waves of calculus reform rolled up onto the beaches of WAC, and consequently all sorts of new treasures washed up on our shores during that era. Historically, the "Writing Across the Curriculum" (WAC) movement has had two major approaches: the "Writing to Learn" approach and the "Writing in the Disciplines" approach. These two approaches highlight a fundamental question facing a mathematical instructor who wishes to assign writing: is the purpose of assigning writing to help the student learn to *do* mathematics (as in the first approach) or to *communicate* mathematics (as in the second approach)? Of course, the goal is usually some combination of both approaches.

Examples of writing assignments whose primary focus are to teach students learn to *do* mathematics include homework sets, journals, process papers, reflections, and summaries. Examples of assignments with a larger focus on teaching students to *communicate* mathematics include proofs, laboratory reports, formal write-ups of solutions to problems, and research papers. We describe some of these examples in greater detail. (Received September 03, 2014)

1106-AG-732 **Jacqueline M. Dewar*** (jdewar@lmu.edu), Loyola Marymount University, Department of Mathematics, 1 LMU Drive UH 2700, Los Angeles, CA 90045. *Could an ecology of teaching and learning inform us about best practices in classroom teaching?*

Haekel coined the term "ecology" in 1866, describing it as "the whole science of the relations of the organism to the environment including, in the broad sense, all the 'conditions of existence' [...] partly organic, partly inorganic [...] the entire relations of the organism to all other organisms with which it comes into contact, and of which most contribute either to its advantage or its harm." This talk will invite the audience to brainstorm what an ecology of teaching and learning might suggest about teaching - at the course or classroom level. Topics we may explore include: course design principles, affective dimensions of teaching and learning, classroom climate, stereotype threat, growth versus fixed mindsets, brain science and learning, and more. Resources will be provided for learning more about these topics. (Received September 05, 2014)

1106-AG-1662 **P. Gavin LaRose*** (glarose@umich.edu), Department of Mathematics, University of Michigan, 530 Church St., Ann Arbor, MI 48109-1043. *What technology should I use—oh, and how does it enhance student learning?*

We teach in an environment where technology is increasingly ubiquitous, in which technology is frequently suggested as a way to teach more "efficiently," and amidst claims that it provides a mechanism for improved student outcomes through changed instruction and pedagogy. And, of course, in the presence of some sense that technology is seen (by some) as a way to move the classroom on-line. In the face of this, it is hard to answer the questions of what technology it really makes sense to use and what impact its use may have. This talk will address some of these questions, though probably not answer all of them. We will explore how we might successfully come closer to the answers we need to use the right technology effectively. (Received September 14, 2014)

1106-AG-2299 **Carol S Schumacher***, Department of Mathematics and Statistics, Kenyon College, Gambier, OH 43022. *What we say/What they hear: Culture Shock in the Classroom.*

In addition to learning specific mathematical content, our students need to learn to think like mathematicians. Indeed, helping them to do this should be at the center of every class we teach. Our students must become immersed in a kind of mathematical "sub-culture" in which they develop skills and practices that allow them to thrive when doing mathematics. Acculturation is most naturally achieved through total immersion in the culture; thus, an inquiry-based classroom in which students are actively engaged in mathematical problem-solving and in which they are required to explain and justify their reasoning is the ideal environment in which to acculturate our students as mathematicians. (Received September 16, 2014)

1106-AG-2713 **Rachel Schwell*** (schwellrac@ccsu.edu). *An Introduction to Best Practices of Modified Moore Method in the Teaching of Proofs.*

Modified Moore Method is a virtually entirely student-driven approach to learning, and it is generally considered to be an extreme version of inquiry-based learning. I will discuss my experiences in teaching proof via this method, and will focus on the "best practices" I have discovered along the way. In particular, I will note how these practices speak to one of my overarching pedagogical goals: transitioning students' perception of mathematics from that of a "cookbook" to more of a "toolbox". Lastly, I will discuss some course logistics, as well as observed outcomes, both measured and anecdotal. (Received September 16, 2014)

1106-AG-2754 **Robin H. Lock*** (rlock@stlawu.edu), Department of Math, CS and Stat, St. Lawrence University, Canton, NY 13617. *Gaising into the Future of Teaching Statistics.* Preliminary report.

In 2005 the American Statistical Association (ASA) approved Guidelines for Assessment and Instruction in Statistics Education (GAISE) that included pedagogical recommendations for introductory statistics courses that are in the same spirit as efforts the MAA's CUTM is working on for instruction in the mathematical sciences more generally. Given rapid changes in statistical practice and technology, to what extent are the GAISE recommendations still relevant a decade later and where might they need refinement? The Common Core State Standards in Mathematics include a greater emphasis on statistics and teaching ideas through simulation-based methods. In what ways might this affect what we do (and how we do it) in introductory statistics at the college level? What are the implications for preparing future teachers to be confident in teaching Common Core statistical ideas? The CUPM Guidelines have long recommended that all mathematics majors take a statistics course. But what course is most appropriate and valuable? Finally the ASA is revising its guidelines for programs (majors and minors) in statistics. Since some programs exist or will grow out of Mathematical Sciences departments, how might the new program guidelines affect what statistics courses we teach and how we teach them? (Received September 16, 2014)

Cartography and Mathematics: Imaging the World Around Us

1106-B1-1089 **Michael A Brilleslyper*** (mike.brilleslyper@usafa.edu), Department of Mathematical Sciences, 2354 Fairchild Drive Suite 6D-124, USAF Academy, CO 80921, and **Mark Staley**. *Maps based on Max Elevation Angles to the Horizon.* Preliminary report.

Topographic maps display 3-dimensional terrain by plotting curves of constant elevation. Often, colors are assigned to different elevation ranges to create vivid 2-dimensional representations of a region. An alternative to measuring elevation at each location is to instead measure the maximum elevation angle to the horizon. By assigning colors to different ranges of elevation angles we obtain maps that have a striking similarity to standard topographic maps. The resulting maps based on elevation angles have important applications to the performance of various satellite systems (particularly GPS), where a receiver on the ground must have direct line-of-sight to a satellite in the sky. This talk is based on a year-long project conducted by Air Force Space Command that used terrain data obtained during the 10-day Space Shuttle Tomography Mission conducted in February, 2000. We will discuss the methodology used to calculate the maximum elevation angles and show various images contrasting elevation angle maps with topographic maps of the same region. (Received September 10, 2014)

1106-B1-1958 **Itai Seggev*** (is+research@cs.hmc.edu), 2000 Trade Center Drive, Champaign, IL 61820. *Flying Around the World: A Journey into Map Projections.*

During to horrible rerouting, I recently flew around the world: Dallas-London-Seoul-Dallas. Trying to console myself, I did a quick estimate the frequent flyer miles I'd rack up by computing the length of the middle parallel in this journey. This, however, turned out to be a significant overestimate. Why was this such a bad estimate? How could I do better, using either naive estimates or some differential geometry? These questions give us a way to introduce to students or reinforce basic conepts associated with map projections. (Received September 15, 2014)

1106-B1-2144 **Chase P. Ashby*** (cashby@nmu.edu), 214 W. Jasper St., Gwinn, MI 49841, and **Josh Thompson** (joshthom@nmu.edu). *Loxodromes and Orthodromes: Two Methods for Computing Perimeters of Geographic Regions and their Applications.* Preliminary report.

Inspired by the sense of humility one feels standing on the shores of Lake Superior, two questions come to mind: a) How does one measure the distance between two points on Earth? b) How can we measure the shorelines of the Great Lakes? In our attempt to answer these questions we develop two methods of computing distances on Earth, one based on loxodromes and the other orthodromes. These methods are analyzed, implemented in MATLAB and are applied to geographical data provided by the National Geophysical Data Center. A list of latitude/longitude pairs representing the boundary of the Great Lakes is used to calculate the total shoreline lengths. These methods can be used to compute the perimeter of an arbitrary geographic region on Earth. (Received September 15, 2014)

1106-B1-2878 **Aaron Fenyes*** (afenyes@math.utexas.edu), The University of Texas at Austin, Mathematics Dept, RLM 8.100, 2515 Speedway Stop C1200, Austin, TX 78712. *The Geometry of The Night Sky (or, An Ape Pointing at The Stars).*

Sailors have long used stereographic projections of the sky, in the form of astrolabes, to work out their positions. If any of them had ever chanced to sail off the edge of the Earth, and found themselves traveling at relativistic velocities among the stars, they could have discovered a new use for their astrolabes: figuring out their velocities. This can be done because when a starship performs a change in heading, described by a Lorentz transformation, the celestial sphere as seen by its passengers shifts by a Möbius transformation, and this correspondence gives an isomorphism between the restricted Lorentz group and the Möbius group. Although this fact is quite classical, textbook treatments of it tend to be short on illustrations. I'll try to give a more visual impression of why it's true. (Received September 16, 2014)

Collaborations between Two-Year and Four-Year Institutions that Create Pathways to a Math Major

1106-B5-1719 **Eric J Kostelich*** (kostelich@asu.edu), Arizona State University, Box 871804, School of Math Sciences, Tempe, AZ 85287, and **Roberto Ribas**. *The Mathematics Mentoring Partnership between the Maricopa County Community College District and Arizona State University.* Preliminary report.

I will describe a mentoring partnership for mathematically talented students at the Maricopa County Community College District in collaboration with the Barrett Honors College at Arizona State University. The program is funded by the National Science Foundation and includes a three-week, half-day summer program for studentswith one to three semesters of calculus at Scottsdale Community College; math majors at Arizona State have an opportunity for an 8-week summer research experience. The goals of the program and student outcomes to date will be discussed. (Received September 15, 2014)

1106-B5-1891 **K. Harrison Holmes*** (khholmes@asu.edu) and **Eric J. Kostelich**. *MCTP: A Partnership between Arizona State University and Maricopa Community Colleges.*

While the benefits of a two-year college are generally apparent, the experience can also seem far removed from the expanse of opportunities available at universities. Fortunately, this is not the case for Maricopa County Community College students. Various opportunities in biology and mathematics have allowed me, and many like me, to experience high level research, present at international conferences and develop polylingual coding skills. Among the most important of these opportunities, MCTP (Mentoring Through Critical Transition Points in the Mathematical Sciences) pairs up community college students with several specialized applied mathematicians, exposing them to fields as broad as numerical analysis, set theory, topology and statistics. Students are briefly exposed to each topic before engaging in hands on research that nurtures computational skills, the reading of scientific literature and communication of complex ideas to a general audience. While in the program, students are also provided educational and career counseling, as well as a preview of future opportunities available at Arizona State University. (Received September 15, 2014)

1106-B5-2313 **Kent Pearce*** (kent.pearce@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409, **Jerry Dwyer** (jerry.dwyer@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409, and **Brock Williams** (brock.williams@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79414. *South Plains Mathematics Fellow Program: A partnership to attract new STEM students as mathematics majors.* Preliminary report.

The Department of Mathematics and Statistics at Texas Tech University (TTU), Midland College (MC), Odessa College (OC), and Mesalands Community College (MCC) have established the South Plains Mathematics Fellows program (SPMF) to attract new STEM students as mathematics majors. This program places an emphasis recruiting on academically talented students from underrepresented, low-income families for undergraduate study leading to a degree in mathematics. These students matriculate at one of the four institutions and participate in mentoring, discovery and research activities during their freshman and sophomores years. The students at the community colleges MC, OC and MCC transfer to TTU at the beginning of their junior year and join the

TTU SPMF cohort for continued mentoring and for undergraduate research experiences during their junior and senior years. (Received September 16, 2014)

1106-B5-2523 **Luke T Walsh*** (lwalsh@cvcc.edu), 2550 Hwy 70 SE, Hickory, NC 280602, and **Katie J Mawhinney** (mawhinneykj@appstate.edu), Department of Mathematical Sciences, 121 Bodenheimer Dr., Boone, NC 28608. *The Tropic of Calculus: No Course Is an Island.* Preliminary report.

Have High Schools, Community Colleges, and Universities evolved into three unique, disjoint islands where students can learn calculus? Curriculum and Pedagogy Alignment were two elements identified in the *Fall* 2012 *Ramping Up for STEM Success* report as successful in supporting transfer student success in STEM undergraduate programs. As a "gateway to the sciences", the first-year differential calculus courses are ubiquitous in secondary, two-year, and four-year school mathematics course offerings, serving as a common ground upon which these institutions could build pedagogical and curricular alignment. But is this happening? This talk explores the distinctions in the teaching and learning of differential calculus at the high school, two-year, and four-year college level. (Received September 16, 2014)

1106-B5-2861 **Rebecca Metcalf*** (rmetcalf@bridgew.edu), 131 Summer St., Bridgewater, MA 02325, and **Irina Seceleanu** (iseceleanu@bridgew.edu), 131 Summer St., Bridgewater, MA 02325. *Creating a Pathway for Transfer: A Partnership between Two-year and Four-year Public Institutions in Massachusetts.*

Transfer has become a significant pathway for obtaining a bachelor's degree from four-year institutions. Over 50% of transfer students at public four-year institutions in Massachusetts come from two-year colleges, making it increasingly important to establish collaborations between these institutions that promote the retention and success of transfer students. In this talk, we present an initiative funded by the MA Department of Higher Education, which supported the alignment of the curriculum and coordinated advising across institutions in Southeastern MA. More specifically, we outline the structure of the collaboration between Mathematics faculty at three community colleges and a four-year university within the public higher education system. In addition to identifying transfer course equivalences for major-level courses, we established common student learning outcomes for courses within the first two years of the major and characterized important knowledge and skills that contribute to the success of transfer students. We also present how the transfer pathway was supported by instituting advising across institutions and helping community college students connect with university faculty prior to transfer. Furthermore, we discuss the challenges and successes of the project. (Received September 16, 2014)

Cryptology for Undergraduates

1106-C1-77 **Jay A Malmstrom*** (jmalmstrom@occc.edu), Mathematics Department, Oklahoma City Community College, 7777 S May Ave, Oklahoma City, OK 73159. *Cryptography Activities in a Mathematics Course for Liberal Arts Majors.* Preliminary report.

Cryptography, as a topic, provides the Mathematics instructor with a unique tool for pulling together materials from a wide range of subjects, including history and literature. In class projects allow the instructor to introduce the mathematics of cryptography in a manner that is both mathematically correct as well as nonthreatening to the student. (Received July 01, 2014)

1106-C1-88 **Chris Christensen*** (christensen@nku.edu). *Recovering Additives from Superenciphered Code.* Preliminary report.

During World War II, to attack the primary Imperial Japanese Navy cipher JN-25, US Navy mathematicians used modular arithmetic to determine all possible additives for columns of enciphered code groups that were aligned in depth. This presentation will describe the mathematically simple attack that is an interesting application of modular addition. (Received July 07, 2014)

1106-C1-259 **Ward Heilman*** (wheilman@bridgew.edu). *Cranks, Rotors, Rods, Algorithms, Quilts and Computations: designing and building encryption devices and methods in a Cryptology course.* Preliminary report.

Students often read about cryptosystems from the Spartan scytale to Enigma, SIGABA, AES and RSA, without tangible comprehension. To help students better understand the components, combinatorics and security behind these and other methods, and to connect them more intuitively to them, students in a Junior level mathematics cryptology course design and build encryption devices or techniques. Some merely recreate objects (like the

Jefferson wheel cipher), some combine or improve on them and some design their own encryption schemes or machines. These have various levels of effectiveness which students compute and evaluate. (Received August 16, 2014)

1106-C1-292 **Cheryl Beaver** and **Stuart Boersma*** (boersmas@cwu.edu). *KRYPTOS: A Cryptanalysis Contest for Undergraduates.*

Since 2011 the authors have been organizing a cryptology contest for undergraduates. No special mathematics ability is assumed, just an interest in code breaking. Originally offered as a regional competition, KRYPTOS has recently attracted competitors from over 16 states and four countries. This paper will describe the competition format, how students can participate, and share a few of the cipher challenges from past competitions. (Received August 19, 2014)

1106-C1-304 **Andrew J Simoson*** (ajsimoso@king.edu), King University, 1350 King College Road, Bristol, TN 37620, and **Thomas H Barr** (tom@entreventures.net), Indian Springs School, 190 Woodward Drive, Indian Springs, AL 35124. *Twisting the Keyword Length from a Vigenère Cipher.*

We give an alternate method to the standard Friedman and Kasiski techniques for determining the length of a keyword in Vigenère-type ciphers using a comparison twist on the sorted frequency vectors of the letter usage in a message. In the numerous times we have experimented with this twist algorithm, it has performed at least as well as the two standard approaches, and oftentimes significantly better. (Received August 20, 2014)

1106-C1-566 **Karen M Holmes*** (kholmes@butler.edu). *Codes and Secret Messages: An Analytic Reasoning Course at Butler University.*

Codes and Secret Messages is a course created to fulfill the Analytic Reasoning requirement as part of the core curriculum at Butler University with the idea that the course would be student discovery based. To that end this course was designed for non-mathematics majors and has a workbook with twenty-nine group activities dealing with cryptography, ranging from anagrams and check digits to the Vigenere cipher and RSA encryption. Each class starts off with an explanation of the day's activity and then, in groups of four, the students work together to complete the workbook pages for the day. The mathematics we do in class varies from logic puzzles and combinatorics to matrices and modular arithmetic. The talk will consist of examples of groups from the workbook and will focus on the Enigma machine and RSA encryption. (Received September 02, 2014)

1106-C1-696 **Tamara B Veenstra*** (tamara_veenstra@redlands.edu). *Cryptology By Discovery: Favorite Inquiry-Based Activities.* Preliminary report.

At the University of Redlands, we offer a one-month intensive term course as our transition to upper level mathematics course. While this course has been offered with a variety of topics, students have responded especially well to using topics from cryptology. One of the most important aspects of making this course successful is incorporating a wide variety of discovery-based activities. In this session I will present some of the most successful activities that I have found/developed for engaging students with cryptology. While this course is designed for first and second year mathematics and computer science majors and minors, recommendations for how these materials could be adapted for other levels will also be included. A link to a website with sample handouts and interactive demos (via embedded Sage cells) will be provided. (Received September 15, 2014)

1106-C1-735 **Jeffrey A. Ehme*** (jehme@spelman.edu), Spelman College, Mathematics Department, 350 Spelman Lane SW, Atlanta, GA 30314. *Locating Large Primes Promptly.*

Many public key cryptosystems depend on the ability to quickly find large random prime numbers. The Miller Rabin test is an excellent method for finding these primes which uses accessible mathematics from introductory abstract algebra. For this presentation, we discuss the Miller Rabin test, how it fits into an Abstract Algebra course, along with some generalizations and class projects. (Received September 05, 2014)

1106-C1-848 **Sharon M Frechette*** (sfrechet@holycross.edu), Department of Mathematics & Computer Science, College of the Holy Cross, 1 College Street, Worcester, MA 01543. *Ciphers and Heroes: Introducing first-year students to the world of cryptology.* Preliminary report.

In 2008, Holy Cross launched Montserrat, a first-year experience that integrates living, learning and doing from students' first day on campus. As part of this program, each student takes a one-year seminar that focuses on a specific discipline, yet emphasizes in-class discussions and collaborative activities. My Montserrat seminar, "Can You Keep a Secret?," introduces students to the mathematics and history of cryptology. In the fall course, "Ciphers and Heroes," students learn about historical ciphers up through World War II, by way of collaborative activities and readings that engage them in the culture of cryptology as well as the mathematics. From learning about the inner workings of the Enigma machine to discussing pulp magazine detective heroes of the 1920s, students spend the majority of class time doing and relating mathematics to other areas of the curriculum. In this talk, I will highlight a few of my favorite student activities from the course, including an Enigma decryption activity using the iPad app Mininigma, and an exploration of Friedman's attack on the running key cipher using an easy-to-make sliding-column tool. (Received September 07, 2014)

1106-C1-1413 **Edmund A. Lamagna*** (eal@cs.uri.edu), Department of Computer Science and Statistics, University of Rhode Island, Kingston, RI 02881. *Decrypting Cryptography.*

Cryptography is an important, contemporary real-world application of mathematics. The subject can be taught at different levels to diverse populations from freshman non-majors to upper level math and computer science students. To assist in teaching such courses, the presenter has created a website with tools for encrypting and decrypting using a representative variety of classical and contemporary techniques. The methods include substitution and transposition ciphers, the Enigma machine, simplified versions of modern block codes (DES, AES), and public key techniques such as Diffie-Hellman and RSA. The site provides both pedagogic tools to trace step-by-step how the methods operate, and computational tools to perform cryptanalytic attacks on classical ciphers. Students use the site to work on problem sets and the tools to crack cryptographic challenges. The website eliminates the need for students to write programs to perform these computational tasks.

The tools are demonstrated by mounting an automated attack on the Vigenère cipher, a polyalphabetic substitution studied in virtually every cryptography course. The statistical and linguistic ideas behind the attack are presented, and then the tools are used to demonstrate these concepts visually. (Received September 12, 2014)

1106-C1-1509 **Michael Olinick*** (molinick@middlebury.edu), Department of Mathematics, 314 Warner Hall, Middlebury College, Middlebury, VT 05753, and **Robert P. Martin**. *Approaching Cryptology Through The Enigma of Alan Turing.*

Courses on the life and work of Alan Turing provide a natural and compelling setting to introduce the mathematical aspects of cryptology to undergraduates. We have developed and taught two such courses: a first year seminar and an intensive winter term class open to all students. Students study classic cryptographic and cryptanalysis schemes including Caesar ciphers, monoalphabetic and polyalphabetic substitutions, Hill and Playfair ciphers, as well as the one time pad as background to understanding the operation and breaking of the Enigma machine. The success of Turing's team on the Enigma code shortened the duration of World War II and saved millions of lives. We also examine Turing's ideas on using the complexity of factorization as a basis for encryption and show how they matured into the RSA algorithm. (Received September 13, 2014)

1106-C1-2104 **Joshua E Hill*** (hillje@uci.edu). *Analysis of Substitution Ciphers.*

Solving a substitution cipher is considered "easy", but it isn't always clear how to programmatically break such systems. We outline a standard letter frequency based approach, and consider why this approach often runs into problems. We then outline the greedy dictionary matching techniques described by Olson. We finally describe some of the standard models for cryptographic security and demonstrate why, under these models, substitution ciphers are considered weak. (Received September 15, 2014)

1106-C1-2276 **Kristi Meyer*** (kristi.meyer@wlc.edu). *More than "Just Math": The Historical Side of Cryptology.*

"When am I ever going to use this?" All mathematics professors have heard this comment from their students more often than they care to remember. Undergraduate cryptology courses, which are continuing to increase in popularity, provide an ideal context for answering this question. In addition to discussing current cryptological techniques which are immediately relevant to students, incorporating historical topics into a cryptology course provides a fascinating glimpse into how cryptology has literally changed the world. In this talk, I will detail how I include these historical topics in my cryptology course via a research paper and presentation. Chosen research topics will be discussed, as well as grading issues and student feedback. (Received September 16, 2014)

1106-C1-2556 **Ann E Moskol*** (amoskol@ric.edu), 2 Longmeadow Rd, Lincoln, RI 02865. *Topics in Steganography: Hiding Text within Text.* Preliminary report.

This talk will present problems in steganography that can be used to help motivate non mathematics majors, or to supplement material in a discrete mathematics course. I will explain the utility of steganography to hide messages, provide a brief history of steganography, discuss the difference between technical and physical steganography, and present problems and projects that can be solved by hiding text within other text. The material for this talk is part of a module that is being developed for use in the classroom through the DIMACS / CCICADA 2014 Reconnect Conference in "Forensics." (Received September 16, 2014)

1106-C1-2843 **Mark Kozek*** (mkozek@whittier.edu), Department of Mathematics, Whittier College, Whittier, CA 90608-0634. *The Mathematics and Politics of Military Cryptography.* Preliminary report.

In this preliminary report we reflect upon our experiences teaching the interdisciplinary course *Numb3rs in W4r & Espion4ge: The Mathematics and Politics of Military Cryptography.*

This course explores mathematical methods in military cryptography and places special emphasis on the political context, the organizational environment, and the war-time consequences of breaking some of these military codes. Students will study and attempt to crack codes used by the military and governments through WWII, study modern computational cryptosystems, and explore current issues in satellite/internet security and communication. Lessons might include mathematical lectures, problem sets, class discussions of readings and viewings, code-breaking exercises, guest lecturers, written responses and major expository papers. (Received September 16, 2014)

Discovery and Insight in Mathematics

1106-C5-249 **Bonnie Gold*** (bgold@monmouth.edu), Mathematics Department, Monmouth University, West Long Branch, NJ 07740. *George Polya on methods of discovery in mathematics.* Preliminary report.

George Polya, in his book *How to Solve It* and more so in his later two-volume *Mathematics and Plausible Reasoning* discussed methods of discovery in mathematics in considerable detail. This talk will examine both the methods he explicitly discussed, as well as some that are, I believe, implicit in his writing. (Received September 07, 2014)

1106-C5-443 **James R Henderson*** (jrh66@psu.edu). *Kepler's Mysterium Cosmographicum.*

In 1596, Johannes Kepler completed his Mysterium Cosmographicum (MC), a bizarre text that "explains" the relative distances from the sun to the six then-known planets in terms of the five Platonic solids (astronomy was, in Kepler's day, largely a mathematical enterprise). It is remarkable that Kepler's utterly misguided model should have produced results as accurate as they were. I will argue that Kepler's reasoning springs from three propositions: (1) Kepler, deeply religious, believed god designed the universe with a necessary, specific, understandable plan; (2) Kepler believed that Copernicus was right about heliocentricity; (3) Kepler believed that mathematics can give rise to knowledge of the physical world. I will discuss these propositions in more depth, trace Kepler's motivation in writing MC, investigate the inspiration of the central idea of the book (the first spark was a single picture), and talk about how the propositions described above shaped MC. Kepler's writing, in which he lays out his thought processes, the false leads he followed, and his missteps along with his successes, makes for fascinating (and lengthy) reading. (Received August 28, 2014)

1106-C5-583 **Daniel C Sloughter*** (dan.sloughter@furman.edu), Department of Mathematics, Furman University, Greenville, SC 29613. *Insights Gained and Lost.* Preliminary report.

Insights and discoveries in mathematics are seldom superseded or replaced in the course of further development. Our understanding of a certain mathematical concept or theory may increase with time, and may even undergo significant reformulation, yet the objects and relations remain, in most cases, unchanged. In contrast, the objects to which theories in the natural sciences refer have changed significantly over time. Even more, the discovery of a new object in modern physics is now a statement of statistics, a reference to a set of observations with a very small p-value. As G. H. Hardy observed, the difference appears to be that "the mathematician is in much more direct contact with reality." This talk will consider the implications of this difference between mathematics and the natural sciences, and then consider one significant exception: how early insights on the nature of a linear continuum, from Aristotle to Bradwardine, have given way to the modern view of the real line, and what may have been lost in the process. (Received September 02, 2014)

1106-C5-838 **Steven R Benson*** (sbenson@lesley.edu), Lesley University, 29 Everett St, Cambridge, MA 02138. *If you're hoping for discovery, put away the handouts!* Preliminary report.

I have observed that students seem to take fundamentally different philosophical approaches to what we might consider identical problem "set-ups", depending on whether or not the problem is given from the text/handout. When given written problems – no matter how open-ended – students tend to treat them as exercises, whereas problems that appear to be "spur of the moment" or that emerge from a classroom discussion are treated in a more exploratory way. I will present specific instances where deep mathematical insights have occurred in a variety of course levels. (Received September 07, 2014)

1106-C5-1594 **Reuben Hersh*** (rhersh@gmail.com). *Mathematicians' proof: "The kingdom of math is within you".* Preliminary report.

A mathematician's informal proof works by enabling others to perceive internally what he/she is trying to show them. I give a simple example, that $S_p(n)$, the sum of the pth powers of the first n integers is a polynomial in $S_1(n)$, if p is an odd number. (*Experiencing mathematics*, starting on page 89.)

English philosopher Brendan Larvor asks, "What qualifies mathematicians' informal proofs as proofs?" A mathematician seeking a proof is working with internal mental models of mathematical entities (numbers, spaces, algebraic structures and so on). You have direct access to your own internal mental models. You observe some properties of theirs, you manipulate them, you relate them to each other and to other mathematical entities. Your separate individual internal mental models match mine well enough that we communicate about them successfully. In mental struggle with your internal mental models, you notice something interesting. Then you want me to "see" what you "see." You hunt for a sequence of steps which will lead me to share your insight. That sequence of steps, which enables me to "see" what you "see", is what mathematicians call "a proof." (Received September 14, 2014)

1106-C5-1714 **Thomas Drucker*** (druckert@uww.edu), Department of Mathematics, University of Wisconsin–Whitewater, 800 West Main Street, Whitewater, WI 53190. *Explanatory and Justificatory Proofs.*

Michael Dummett has pointed to the difference between explanatory and justificatory proofs. It is also a distinction familiar to those who have to explain to a class that mathematical induction does not give the user a way to discover what is to be proved, but only to justify a particular result. As students proceed in their studies of mathematics, proofs that may originally have seemed purely justificatory take on an explanatory structure. This talk will look at Dummett's distinction to see if it is more than a reflection of the level of mathematical experience of the prover. (Received September 15, 2014)

1106-C5-1803 **Carl E. Behrens*** (behrenscarl@yahoo.com). *How does the mind construct/discover mathematical propositions?* Preliminary report.

Recent discoveries in cognitive science probe deeply into the mental processes of mathematicians as they practice their art. George Lackoff and Rafael Nunez have focused most extensively on the roots of mathematical subjects, proposing that much advanced mathematics derives from schemas and conceptual metaphors used and developed for more common purposes. But other cognitive scientists, among them Antonio Damasio, Stanley Greenspan, and Stuart Shanker have directed their attention to the role of emotions in the practice of rational thought. Greenspan and Shanker argue that the ability to create symbols and to reason is not hard-wired in the human brain, but is actually learned through emotional signaling beginning in the first year of life. This presentation will attempt to tie together these various threads from cognitive science into a view of how mathematics develops and is practiced. (Received September 15, 2014)

1106-C5-1961 **Ruggero Ferro*** (ruggero.ferro@univr.it), Universita' di Verona, Dipartimento di Informatica, Strada le Grazie 15, 37134 Verona, VR, Italy. *An analogy to help understanding Discovery, Insight and Invention in Mathematics.*

An analogy with the discovery of how life would be evolving in a town to where one is moving in may help us to understand what could be meant by discovery, insight and inventing in mathematics. The key common features of these two environments that I will try to point out range from 1) the realization that anything observed is contingent; to 2) the very reasonable hypothesis that anything that was build responded to some need, requirement, convenience or development; 3) what was previously constructed has some influence and bearing on what is done afterwards; 4) an understanding of the motivation of what was done and of the manner in which it was realized are needed to continue the construction; 5) the needs and requirements are continuously evolving and newly invented artifacts or improvements should be added to face them; to 6) not every invented addition meets the situation and the requirements with the same short range and long range convenience, thus a preventive evaluation is convenient according to criteria to be established. I will also try to underline the difference between the attitude proposed and the one claiming that in mathematics everything ought to be so, it can't be but so, due to an a-priori mental evidence, since this is the truth. (Received September 15, 2014)

1106-C5-2391 **Tom Morley*** (morley@math.gatech.edu), School of Math // Georgia Tech, 686 Cherry St // Skiles Build, Atlanta, GA 30306. *Some proofs and discoveries from Euler and Heaviside.*

We give several examples of proofs that would not be considered proofs by contemporary Mathematicians, of correct theorems and calculations of Euler and Heaviside, including Euler's remarkable approach to zeta of even integers, and Heaviside's solution of the age of the earth partial differential equation . Although both of these examples can be "rigorized" by modern techniques, that is not the point. We pose more questions than answers. (Received September 16, 2014)

1106-C5-2535 **Horia I Petrache*** (hpetrach@iupui.edu), Department of Physics, Indiana Univ. Purdue Univ. Indianapolis, Indianapolis, IN 46202. *Removing bias: the case of the Dirac equation.* Preliminary report.

I will argue that inherent human bias is often in the way of discovery. However such bias becomes obvious only in retrospect, after discovery is made. The Dirac equation for electrons and positrons is one such example of the interplay between mathematical insight and discovery. By attempting to reconcile Schrodinger equation with spacetime invariance, Dirac has used the insight that the four dimensions in spacetime needed to be put on equal footing. Although this requirement was obvious, the mathematical approach was not: it required relinquishing the natural bias that coefficients appearing in the equation must be simple commuting numbers. Once this bias was removed, Dirac equation led to new discoveries involving spinors and bispinors as the appropriate mathematical construction for fermions. It also predicted the existence of positrons, the antiparticle of electrons, as the "extra" solutions of the equation. I will discuss briefly the Dirac equation and how it further led to the use of covariant derivative in the standard model of interactions. (Received September 16, 2014)

1106-C5-2763 **Kira Hylton Hamman*** (kira@psu.edu), 1 Campus Drive, Mont Alto, PA 17237. *Intuition: A History.*

What is intuition, and what is its role in mathematics? I don't know, and neither do you, but many a distinguished scholar has speculated on these questions. We trace the trajectory of our understanding of mathematical intuition from the Greeks through the Enlightenment and into the present day. And while you probably will not emerge from this talk with answers to these compelling questions, you will at least be prepared to approach them with an understanding of where we have been. (Received September 16, 2014)

Ethnomathematics: A Tribute to Marcia Ascher

1106-D1-28 **James V Rauff*** (jrauff@millikin.edu), Department of Mathematics, Millikin University, 1184 W. Main St., Decatur, IL 62522. *The Ethnomathematics of North American Rock Art.*

In her eponymous first book on ethnomathematics, Marcia Ascher reminds us that shared mathematical ideas may be differently expressed and have different contexts in different cultures. The ancient pictographs and petroglyphs found painted on or carved in rocks include manifestations of geometric, numeric and algebraic ideas. We cannot know for certain the intentions of the prehistoric artists who created this rock art. Nevertheless, the figures they carved and the relationships between those figures are archaeological records of mathematical thinking. This paper examines some of the mathematical ideas embodied in the rock art of the American Southwest, the Great Plains, and the Pacific Northwest. (Received May 01, 2014)

1106-D1-383 **Charles Peter Funkhouser*** (cfunkhouser@fullerton.edu), **Miles R. Pfahl** and **Harriet C. Edwards**. *Discovering Universal Connections in Mathematics Through Native American Culture.*

This session presents mathematics materials based in the culture and mathematics of Native American Peoples for integration into undergraduate courses. These materials–both paper and electronic–are classroom ready, and are developed and piloted in consultation with Tribes throughout the West, and suggest the universal nature of mathematics across cultures. This research is an NSF DUE funded Project (#1122823). (Received August 26, 2014)

1106-D1-587 **Thomas E. Gilsdorf*** (thomas.gilsdorf@itam.mx), Departamento de Matemáticas, Rio Hondo #1, Colonia Progreso Tizapan, 01080 Mexico City, D.F., Mexico. *Women and Ethnomathematics: Aspects of Gender.*

In Western culture there is a long history of de-emphasizing the mathematical aspects of work done by women. Work by women such as weaving or making designs and artwork often includes mathematical activities. Moreover, in some cultures the mathematical skills of women is highly respected and their work is important to the success

of the culture in general. Research by Brumfiel, Hendon, M. Ascher and others, have shown the cultural importance of mathematical activities of women in various instances. I will discuss specific examples of such activities, including the role of weaving by women of Aztec, Otomi, and Inca cultures, as well as mathematical aspects of work by women in India who create patterns called Kolam. (Received September 02, 2014)

1106-D1-623 **Anne M Raymond*** (araymond@bellarmine.edu), Mathematics Department, Bellarmine University, 2001 Newburg Road, Louisville, KY 40205. *An Island Divided: Diversity and Mathematics on St. Maarten.*

The history of the island of St. Maarten is rich with the blending of many cultures in the Caribbean, South American and Europe. The current division of the island into two primary countries, The Netherlands and France, was determined in 2001 and has the potential to evolve yet again. The mathematics of the island primarily center around economic issues, tourism (the main industry), dance and education. This paper focuses on the Dutch side of the island examining the variety of educational choices, the mathematics curriculum, mathematical expectations of the education system and the historical and current connections to island life. Data from national documents and first-hand interviews with members of the ministry and practicing mathematics teachers is analyzed across these areas. Implications from this research for the mathematics classroom and for mathematics teacher education are shared. (Received September 03, 2014)

1106-D1-784 **Deepak Basyal*** (deepakji@nmsu.edu). *Śiśubodha Taraṅgiṇī: A 1933 mathematics and astrology book from Nepal, its content and backstory.* Preliminary report.

This report is a study of a 1933 book of mathematics and astrology, written in Nepali and Sanskrit, Śiśubodha Taraṅgiṇī, (loosely titled A series of lessons for children), long thought to be lost. By contacting researchers and relatives of the purported author in Nepal, and via investigation of rare book collections in the United States and Nepal, a copy was found. The title page of the book indicates that it was written by Chandrakala Dhananjaya, a female. But again via some searching, it was with almost 100% certainty written by her husband, Tikaram Dhananjaya. It contains about 137 slokas, short “poems” containing mathematical rules and problems, mostly for young learners. I am making a translation of it into English, and I will describe its provenance and its contents, including some atypical problems and their solutions, as well as its connections to other historical works in Nepal and India (e.g., Bhaskara’s Lilavati). I will show how some of the problems are adapted to specific Nepalese cultural and economic contexts. I will also describe the educational/political situation in Nepal in the 1930s and why it may have given rise to the book’s unusual backstory. (Received September 06, 2014)

1106-D1-815 **Cynthia E. Taylor*** (cynthia.taylor@millersville.edu). *Shongo Networks–A Sand Graph.*

Shongo Networks, a unicursal network, have been used by Bushoong children, from the Angola/Zaire region in Africa, when playing games in the sand as well as by storytellers to represent events and changes in stories as they are told. Interesting relationships exist between the various Shongo Networks of the first kind, which refer to the number of units moved initially. In this presentation, a sample lesson taught to undergraduate students will be introduced with exercises. (Received September 07, 2014)

1106-D1-1165 **Victor J. Katz*** (vkatz@udc.edu). *Marcia Ascher and Ethnomathematics.*

Marcia Ascher was one of the early proponents of the study of ethnomathematics, a field named by Ubiritan D’Ambrosio in his address at ICME 5 in 1984. Her books and articles helped stimulate discussion about the nature of mathematical ideas and how they find their expression. ”Mathematical ideas” for her were ideas “involving number, logic, spatial configuration, and, more significant, the combination or organization of these into systems and structures.” She was able to find numerous examples of such ideas in “traditional” cultures, cultures which were generally non-literate in our sense. In this talk, we will discuss some of her significant contributions to the field of ethnomathematics and explain why they have continuing implications today. (Received September 11, 2014)

1106-D1-1849 **Ximena Catepillan** (ximena.catepillan@millersville.edu), Department of Mathematics, Millersville University, Millersville, PA 17551, and **Waclaw Szymanski*** (wszymanski@wcupa.edu), Department of Mathematics, West Chester University, West Chester, PA 19383. *Remarks on Vedic Arithmetic - multiplication.*

Vedic Mathematics is the name given to the ancient system of Hindu Mathematics which was rediscovered from the Vedas between 1911 and 1918 by Sri Bharat Krsna Tirthaji (1884-1960). According to his research, all of Mathematics is based on sixteen sutras or word formulae. A method of multiplying natural numbers based on Sutra 3 Vertically and Crosswise, called the Urdhva Tiryak Sutra (in Sanskrit), will be presented. The method, which allows to multiply numbers faster than the method currently taught in schools, has been successfully lerned by students at the undergraduate level. (Received September 15, 2014)

1106-D1-2649 **Edwin (Jed) P Herman*** (eherman@uwsp.edu), University of Wisconsin-Stevens Point, Department of Mathematical Sciences, 2001 4th Avenue, Stevens Point, WI 54481. *Ethnomathematics in a First Year Seminar.*

I teach a Freshman Seminar at the University of Wisconsin-Stevens Point called "Are Numbers Real?" I want students to question the form, operations, even the meaning of the numbers they simply take for granted. Is mathematics universal, or is it tied to our perceptions and our culture?

The course opens with an ethnomathematics-like component which fills about 30% of the course time. Much of the material focuses on the linguistics of counting words and what the words tell us about a culture and how its members might perceive numbers – though we do touch lightly upon other cultural aspects of numbers as well, primarily in Polynesian cultures. We also spend time studying early historical counting systems for similar reasons.

In my presentation I will discuss the topics and material covered in this course component, as well as examples of student work. Student feedback for the course in general and this section in particular will be discussed, as well as a short list of resources I found helpful in developing the course. (Received September 16, 2014)

1106-D1-2674 **Jennifer Wilson*** (wilsonj@newschool.edu). *Comparing Traditions of Fairness.*

This talk will compare mathematical approaches to sharing resources in three traditions: the division of loaves of bread from the Egyptian Ahmes Papyrus, the "Talmud Rule" for competing claims, and the Islamic inheritance problems analyzed in al-Khuwarizmi's "al-jabr w'al-muqabala." We will discuss the fairness principles underlying these traditions and place them in the context of contemporary math literature in the fields of fair division and resource allocation. (Received September 16, 2014)

1106-D1-2793 **Ivan Lina-Ramos*** (ivanlinacedart@gmail.com), Raul Herrera #92, Barrio San Miguel. Delegacion: Iztapalapa, Mexico, City, 09360, and **Alma Fabiola Rangel-Chavez**. *The role of an alternative natural language based on Mesoamerican concepts in teaching algebraic processes.* Preliminary report.

The purpose of this pilot study was to explore an alternative natural language based on the Mesoamerican concept of complementary opposites for teaching Algebra. The goal is to develop a learning-oriented pedagogy based on the Mesoamerican cosmovision.

Complementary opposites is the concept that refers to the way Mesoamerican societies organize the world in paired dualities, like dry and wet or life and death (Lopez Austin, 2008). Based on this concept and using different narratives from Aztec myths, we introduced the term complement, which relates to the inverse operation used in algebraic processes.

Data was obtained by observing students' mathematical discourses in a Mexican high school, while they solved algebraic problems in teams. A frequency analysis was made comparing the use of precise mathematical language versus alternative natural language. Results show that medium and low-achieving students quickly adopted the alternative natural language, reducing their algebraic misconceptions and improving their mathematics performance. High-achieving students continued using the precise mathematical language. However, all students showed empathy for the use of Mesoamerican concepts in their algebraic learning and fostered students accountability for learning. (Received September 16, 2014)

1106-D1-2829 **Betty C Rogers*** (brogers@piedmont.edu). *A Unique and Successful Course in Multicultural Mathematics.*

The highly successful "Multicultural Mathematics" course at Piedmont College focuses on the historical development of non-Eurocentric mathematics in societies ranging from Central and South America through the African and Islamic countries to the Far East. This presentation discusses the basics of the class and why it has become such a well-liked course by secondary and middle grade graduate mathematics education students as evidenced by enrollment statistics, student comments and course evaluations. The majority of those enrolled in the class are teachers from an area where schools have highly diverse populations. Teachers who complete the course feel it prepares them to better relate to students from other cultures and to appreciate the impact of mathematical contributions of varied civilizations. Others have stated that knowledge of this unique mathematical history allows them to develop applications, problems and lesson plans that better connect with their minority students. (Received September 16, 2014)

1106-D1-2886 **Darrah P. Chavey*** (chavey@beloit.edu), Beloit College, 700 College St., Beloit, WI 53511, and **Philip D. Straffin, Jr.**. *Game Analysis of Mu Torere and Related Ethnographic Games.*

In "Mu Torere: An Analysis of a Maori Game," Marcia Ascher did the first graph theoretic analysis of the Maori game Mu Torere, and argued that similar games of this form on different size boards would not be interesting. We provide an alternative analysis of Mu Torere which simplifies the game graph enough that certain aspects of the play of the game and its complexity are easily revealed: in particular, showing that optimal play in Mu Torere produces a draw. We also describe games of this same form, but on smaller boards, from China, Korea, and from a "Berry Berry Kix" cereal box that show that alternative formulations of this game could, in fact, be interesting. In further analysis of these several games, we apply a series of simplifications of the game graphs by using assumptions that players can see some number of steps ahead. These successively simplified graphs reveal additional insights into the complexity of this class of ethnographic games. (Received September 17, 2014)

First-Year Calculus: Fresh Approaches for Jaded Students

1106-D5-881 **Fred Halpern*** (fredhalp@gmail.com). *Integration by Guessing.*

We illustrate Integration by Guessing: guess, differentiate to check the guess, and then adjust to get an exact fit. It is a simple and powerful methodology, useful in many situations.

The adjustments are of two kinds: 1. If the guess is off by a factor, divide by the factor. 2. If the derivative of the guess has an extra term, then subtract the integral of the term from the guess (One use is integration by parts).

Standard integration techniques, substitution and Integration by Parts, begin with a hidden guess. Recognizing the role of hidden guesses leads to shortcuts that simplify your work, avoiding tedious, distracting calculations.

We also illustrate the power of a theorem of Pease and provide a proof using guessing. Pease's theorem provides easy solutions to many integration by parts problems where the guessing method is not directly applicable. (Received September 08, 2014)

1106-D5-888 **Stephen Kokoska*** (skokoska@bloomu.edu), Dept of Math, Computer Science, & Statistics, Bloomsburg University, Bloomsburg, PA 17815. *AP Calculus: Student preparation for college mathematics.*

Many first-year college students who enroll in calculus have previous experience with this subject, most often from Advanced Placement (AP) Calculus courses. In 2014, over 400,000 AP Calculus exams were administered to students enrolled in a year-long, well-established course. The AP Calculus community is committed to student success in future mathematics courses and works closely with colleges and universities to ensure the consistency and reliability of the course. Those students who complete an AP Calculus course and are successful on the AP Calculus exam have demonstrated appropriate conceptual understanding, analytic skills, and problem solving ability. The purpose of this presentation is to summarize the goals and topics of AP Calculus and provide behind-the-scenes details about the AP Calculus Reading and the grading process. A typical free response question will be presented along with the grading standard to give a specific example of expectations. (Received September 08, 2014)

1106-D5-912 **Eric J. Landquist*** (elandqui@kutztown.edu), Department of Mathematics, Kutztown University, Kutztown, PA 19530. *Operation Nonabelian Grape: Transforming Calculus I into a Top Secret Mission.* Preliminary report.

A highly classified prototype "fluxion coil" has been stolen from a government lab and is being taken around the globe to be auctioned on the black market by an underground syndicate called PseudoWho. It is the mission of teams of agents to follow clues encoded in the solutions of calculus problems to track down and recover the fluxion coil. Problem sequences lead teams to informants to help them in their mission. Can teams solve mathematical puzzles and crack codes to obtain bids from interested parties? Can they blast a road having continuous derivatives out of a mountain pass in order to infiltrate a PseudoWho compound? Can they minimize their escape time to flee from terrorists? In Operation Nonabelian Grape, Calculus I is transformed into a semester-long treasure hunt to make the often mundane task of mastering key concepts into an exciting challenge and help students have more persistence in the problem-solving process. Problems range in difficulty to challenge each student at their ability level. Other activities encourage students to participate in class, seek help when they need it, and expose themselves to mathematics outside the classroom. This talk will share my version of a treasure hunt that I use in my Calculus I classes, along with the responses of students. (Received September 08, 2014)

1106-D5-1094 **Rebekah Gilbert*** (rgilber1@illinois.edu), 273 Altgeld Hall, 1409 W Green Street, M/C 382, Urbana, IL 61801. *Using computers to challenge misconceptions of "been there, done that" calculus students.*

During the Fall 2014 semester, we experimented with incorporating interactive Mathematica demonstrations into two large-lecture sections of Calculus I at the University of Illinois which served five hundred students who had previous exposure to calculus. Our innovations for these classes were twofold. First, we challenged the common misconception that calculus consists merely of memorizing formulas. We accomplished this by incorporating the demonstrations into active discussion assignments in order to help the students better visualize the important concepts of calculus. Second, we confronted students' unreserved trust in computers and graphing calculators as a substitute for analytical skills honed when solving problems with pencil and paper. By utilizing demonstrations in which the computer produces results that are inexact and sometimes manifestly incorrect, we taught the students the importance of critically evaluating computer-generated results by comparing with analytical work. We evaluated the effectiveness of these innovations in several ways. In the Spring 2015 semester, we will teach Calculus II courses with a similar structure, informed by our findings from Calculus I. (Received September 10, 2014)

1106-D5-1368 **Margaret Nikolov*** (nikolov@usna.edu), Department of Mathematics, United States Naval Academy, Annapolis, MD 21402, and **Wm. Douglas Withers** (wdw@usna.edu), Department of Mathematics, United States Naval Academy, Annapolis, MD 21402. *Finessing Imperfect Calculus Mastery with Embedded Review.*

A technically-oriented four-year college finds most entering freshmen have previously studied calculus, but score insufficiently on validation criteria to place out of even one semester of college calculus. We propose a new course structure to address the needs of such students as an alternative to repeating a year of calculus. Topics from Calculus III are introduced without formal review of topics from Calculus I-II, but with additional time allotted for review just-in-time, on-demand, and in context. Even with additional time for review, students in the new course sequence complete Calculus III within two semesters of entering college rather than three. The new course sequence was tested in a pilot study. Students taking the new two-semester calculus sequence were compared to the rest of their cohort taking the standard three-semester sequence at several stages, based on their performance on multiple-choice questions common to both sets of final exams. Statistically significant differences in the proportion of students answering correctly were found on five of fourteen multiple-choice questions examined (with $\alpha = 0.05$ and correction for multiple testing); on all but one question, students in the new calculus sequence performed better than those in the standard sequence. (Received September 12, 2014)

1106-D5-1485 **Tiernan R Fogarty*** (tiernan.fogarty@oit.edu), Owens 101, 3201 Campus Drive, Klamath Falls, OR 97601-8801. *Numerical differentiation and integration in first year Calculus. Examples of computational exercises.*

A large percentage of students in my first year calculus courses have typically seen the material before either in high-school or in the same course during a previous term. In an attempt to re-engage these students, I have found myself assigning more computational projects that require the students to program numerical differentiation and integration methods. These exercises are always part of an extended project where the students are expected to complete a technical report detailing solution methods and comparing results from various numerical techniques with analytical solutions. Such projects always require that graphical results are generated via student-written code and thoroughly explained.

In this presentation I will share examples of projects I have required in both differential and integral calculus courses. Projects are designed with the assumption that students have never seen the material in the course before nor have any programming ability. I do spend a few (maybe two or three) days in a computer lab with the class to help introduce basic programming to those who need it. In my experience students have responded very well to this type of exploration of calculus and I have received a great deal of positive feedback on these projects from former students. (Received September 13, 2014)

1106-D5-1607 **Frode Rønning*** (frode.ronning@math.ntnu.no), Dept. of Mathematical Sciences, NTNU, 7491 Trondheim, Norway. *Teaching calculus to large and diverse groups of engineering students.*

The Norwegian University of Science and Technology enrols more than 1600 new students each year to a wide range of study programmes in technology. These students are of the most highly qualified in Norway and for some of the study programmes top grades are required. In other programmes the requirements are less strict, making a diverse group of students. However, all students are subject to the same exam.

Comparing Calculus 1 to the courses required to take in school to get admitted one might infer that much of the content is the same. Still, the performance of the students is below what would be desired and perhaps also expected.

Recently a major research and development project has been launched to revise the teaching of the basic mathematics courses. The main aim of the project is to increase the learning outcome in the sense that students should develop a deeper understanding of mathematical concepts and processes. Important keywords for the projects are quality (e.g. in teacher-student interaction), accessibility and differentiation, by creating a variety of resources aiming at students with different interest and motivation.

The project is being research on in various ways, and this presentation will present both the project and some of the experiences. (Received September 14, 2014)

1106-D5-1784 **Mike May*** (maymk@slu.edu), Department of Math and Computer Science, Saint Louis University, 221 N Grand Blvd, St Louis, MO 63103. *Teaching Business Calculus as a Terminal Course Focused on Business.* Preliminary report.

This project looks at replacing the one semester applied calculus course with a course focused on the needs of business students taking calculus. The traditional business calculus course needs to deal with a pair of issues. Many of the students have seen calculus from high school. Since it is often the last math course taken, the students are also unmotivated and see little connection between this course and the courses in their major. Furthermore, most texts are technology agnostic and are generally written for business and the life sciences, so the problems are not focused on business concerns.

At Saint Louis University, the students taking the one semester survey of calculus course are almost all business students. We have developed a text aimed at those students. The examples and language of the text is consistent with what is used in business course. The main computational technology is Excel. In work, readability is encouraged over efficiency of symbolic manipulation. The shift to a truer business focus makes the material feel new for students who have previously seen calculus and gives a better entry point for students with weaker manipulation skills. (Received September 15, 2014)

1106-D5-1828 **Vincent J. Matsko*** (vince.matsko@gmail.com). *Calculus Reshuffled.*

Most calculus textbooks present calculus in a linear, mathematically coherent way – developing one topic before it is needed for the next. But this type of presentation does not reflect the way most students learn, nor does it provide a motivation for why certain topics are important. Rearranging the order of topics in first-year calculus can provide this motivation while still maintaining mathematical rigor. (Received September 15, 2014)

1106-D5-1889 **Kimberly O. Muller*** (kmuller@lssu.edu), 650 W. Easterday Ave., School of Mathematics and Computer Science, Sault Ste. Marie, MI 49783. *Early Continuity, Then Communicate, Communicate, Communicate.* Preliminary report.

In many cases the first month of teaching college calculus can be the hardest. Early student work is often fraught with (1) the misuse or underuse of signs of equality, (2) algebraic errors, (3) incorrect use of procedures when finding limits, and (4) premature use of derivatives before that material is covered. These errors are caused by poor prerequisite skills, misconceptions and perceived low expectations. Much of this can be prevented before the first test day by requiring that students not only show their work but explain their work in writing in each of the formative assessment activities leading up to the exam. In class, it is emphasized that communication is a necessary collegiate skill. Teaching an intuitive definition of continuity early in the course gives the students the vocabulary needed to effectively communicate about limits. Through thoughtful grading of these writing assignments the instructor is able to correct many misconceptions and thus prevent common errors. (Received September 15, 2014)

1106-D5-1896 **Anders K H Bengtsson*** (anders.bengtsson@hb.se), Allégatan 1, 50190 Borås, Sweden, and **Dragu Atanasiu** (dragu.atanasiu@hb.se), Allégatan 1, 50190 Borås, Sweden. *New Teaching Metaphors in Calculus.* Preliminary report.

We present teaching ideas in calculus ranging from global examples on how to approach the subject as such to local of how to approach its parts. A global example is to pivot a course in calculus on polynomials: start the course and do as much as possible with polynomials and then introduce transcendental functions through Taylor series. Avoid limits to begin with and work algebraically as much as possible. In this context we present how the mean value theorem can be made plausible for polynomials using Mathematica experimentation. Working with polynomials grounds the subject in concrete manipulations that are useful by themselves and the step to power series is natural and easy to illustrate with mathematical software. It allows for easy access to the subject's historical roots. A local example is to turn the usual sequence of concepts and proofs leading up to the derivative on its head, and state the definition without prior preparation and then subject it to text analysis much as a poem is first read and then subjected to analysis as done in literary criticism. The idea is that the logical structure of the subject is not necessarily the same as the didactical structure. The aim of the project is to collect new teaching ideas in order to infuse an old subject with new life. (Received September 15, 2014)

1106-D5-2019 **Meghan M De Witt*** (mdewitt@stac.edu). *Calculus comes to life-creating a visual of your math homework.*

We discuss various projects students may engage in to help them realize the beauty and versatility of calculus. This includes everything from baking, to artwork, to physically constructing models to help the student understand the concepts and formulas. (Received September 15, 2014)

1106-D5-2086 **Yevgeniy V. Galperin*** (egalperin@esu.edu), 200 Prospect St., East Stroudsburg, PA 18301. *Derivatives, Edge Detection, and Image Sharpening.*

Many Calculus students struggle with the definition of the derivative because they consider it irrelevant from the practical point of view. We help students appreciate the importance of the definition by working out several derivative-based edge detection methods (the 2x2 Roberts operator, the Prewitt and Sobel kernels, and the Laplacian edge detector). This approach also provides the students with an opportunity to experiment with image enhancement (such as image sharpening) and with Matlab programming. (Received September 16, 2014)

1106-D5-2231 **Debra L Mimbs*** (dmimbs@leeuniversity.edu), 1120 North Ocoee Street, Cleveland, TN 37320. *Using Mathematical Modeling in Calculus.*

I present a problem from a standard Calculus 1 course with an emphasis on mathematical modeling. Even students in Calculus 1, without advanced mathematical knowledge, can benefit from introducing a modeling perspective early. The problem is presented with adaptations and further considerations offered, and an evaluation of the impact this method has on student learning is also analyzed. (Received September 16, 2014)

1106-D5-2348 **Jessica M Libertini*** (libertinijm@vmi.edu), **Caitlin Phifer** and **Erica Sevey**. *Fading the Jade: Using an exam correction/reflection assignment in calculus to promote metacognition and course navigation skills for freshmen who think they know it all but don't... yet.*

One of the challenges of teaching a calculus course to mostly freshmen is that our students come from different high schools and have different levels of exposure, mastery, and awareness of their own strengths and weaknesses with respect to calculus material. Students will frequently try to coast on the material they recognize. Instead of engaging with the material anew, weaker students will repeatedly make the same conceptual errors because they've "seen this stuff before." Stronger students are often fine coasting until the course covers material that is new to them later in the semester; then, unlike their peers, they have no experience with learning in the construct of the current course. At the University of Rhode Island, we proposed and implemented a required exam correction and metacognition assignment that affords all students the opportunity to wrestle with their misconceptions, to identify their common error trends, and to learn how to navigate the course by relating exam questions to course material. This assignment has been tailored to maximize student benefit while minimizing the time input required from instructors. In this talk, we will present our assignment, give examples, and provide feedback from both students and instructors. (Received September 16, 2014)

1106-D5-2450 **Angie Hodge*** (amhodge@unomaha.edu) and **Janice Rech** (jrech@unomaha.edu). *Inquiry as a way to engage ALL calculus students.*

Teaching calculus in an active, inquiry-based approach can create a new set of challenges for the instructor. How do you create activities that challenge students who have already been exposed to the material? How do you truly engage students who aren't really discovering the material, but are seeing it for a second (or maybe even third) time? In this session, we will share our challenges in an inquiry-based learning calculus class and how we have overcome these challenges over the last three years of teaching calculus in a active manner. (Received September 16, 2014)

1106-D5-2499 **Girija S Nair-Hart*** (nairhaga@uc.edu), 3585, Applewood drive, Amelia, OH 45102. *Rediscovering the Power and Joy of Calculus with First Year College Students.*

The challenges posed by first year calculus students stem from a variety of complex issues. One such issue relates to students' difficulties in coping with the expectations of college level calculus courses as they hold legitimate differences from their high school calculus experience. The goal of college calculus curriculum, the methods of instruction, the emphasis on problem solving procedures, the means used to assess student knowledge, the placement methods through which students gain access to these courses are all contributing factors to students' stressful calculus experience. Consequently many of these students for the first time feel that they are not good enough to succeed in their chosen major since they are unable to function well in the calculus courses that their program requires. Additionally, many students are concerned about the monetary waste if they become unsuccessful in calculus courses. These fears along with their self-efficacy and self-concept issues, these students can pose dire desolation for themselves and the instructors of calculus courses. During this presentation, I will highlight steps that could be taken at all levels of the college community if they view students' long term success as the ultimate goal of higher education. (Received September 16, 2014)

1106-D5-2541 **Elizabeth A Miller*** (`elizmiller@math.osu.edu`), 100 Math Tower, 231 W 18th Ave, Columbus, OH 43210, and **Carolyn Johns** (`johns.125@math.osu.edu`). *Flipped and Flexible Calculus: A Different Calculus Experience.*

Ohio State teaches a section of Calculus 1 and Calculus 2 each semester in our new Flipped and Flexible format. This format is more flexible for student schedules, is able to be taken from a distance, is open to high school students for post-secondary credit, and implements the educational theories of active learning in the flipped classroom. The traditional lectures are completely replaced with online lessons which include videos, scaffolding, quiz questions, and choices for students such as what they want to learn next or how many examples they would like to see. Students are able to review these lessons as many times as they like. Recitation sections feature guided group work, allowing students to master concepts with instructor assistance. Students can attend recitations from a distance when necessary. This format reduces class time from 5 hours a week to 2 hours a week. The goal of this course format is to assist students who need a more flexible format without sacrificing any of the academic depth or rigor of the course. Students are supported from a distance through online tutoring, email, and a class discussion board in Piazza. This course format allows students to perform similarly on common department exams to students in more traditional settings. (Received September 16, 2014)

1106-D5-2631 **Dana C. Ernst*** (`dana.ernst@nau.edu`). *A guide-on-the-side approach to calculus.* Preliminary report.

Rewind a few years. Glowing student evaluations, as well as recurring teaching awards, indicated that I was effectively doing my job. However, two observations made me reconsider how well I was really doing. Namely, many of my students seemed to heavily depend on me to be successful and retain only some of what I had taught them. Inspired by a desire to address these concerns I began transitioning away from "sage on the stage" towards "guide on the side." In particular, I began adopting an inquiry-based learning (IBL) approach in my proof-based courses. Yet, due to larger class sizes, significant content expectations, and a desire to maintain some level of sanity while I retooled many of my courses, I continued to teach calculus via direct instruction. Fast forward to the present. Consistent with a growing body of evidence, I have witnessed improved student outcomes in my IBL courses, as well as in subsequent courses. Compelled by my experiences, together with an increasing number of students in my first-semester calculus courses that have previously taken calculus in high school, I decided it was time to chuck my lecture notes and embrace an IBL paradigm in calculus. In this talk, I will relay my experience teaching calculus in the fall of 2014 using a modified-Moore method. (Received September 16, 2014)

1106-D5-2772 **Jody Sorensen*** (`sorensj1@augsburg.edu`), 3725 41st Ave S, Minneapolis, MN 55406. *A Fresh Start: Reordering Calc II in the Fall.* Preliminary report.

Fall sections of Calculus II are famous for having a broad range of student backgrounds and abilities. I decided to tackle this issue by starting the course with a topic that few students would be familiar with: differential equations. In my talk I'll share the changes I made and the impact this had on my students' attitudes and achievements in the course. (Received September 16, 2014)

1106-D5-2883 **Paul E Seeburger*** (`pseeburger@monroecc.edu`), 1000 E. Henrietta Rd., Rochester, NY 14623. *Making Calculus More Engaging with WeBWorK and Visualization.* Preliminary report.

A discussion of the impact of WeBWorK on my Calculus II course and a brief tour of several Java applets I've developed to help students visualize calculus. Although I have developed over 100 applets for various calculus textbooks, all of the applets demonstrated in this presentation can be found on my webpage. Illustrated concepts include piece-wise functions, tangent lines, sketching derivative graphs from the graph of a function, Riemann sums, accumulation/area functions and the Fundamental Theorem of Calculus, slope fields, washer and shell methods, volumes with a common cross-section, etc. See http://web.monroecc.edu/calcNSF. (Received September 17, 2014)

Helping Students See Beyond Calculus

1106-E1-305 **Michael Dorff*** (mdorff@math.byu.edu), 310 TMCB, Department of Mathematics, Brigham Young University, Provo, UT 84602. *Shortest paths, soap films, and mathematics.*

In high school geometry we learn that the shortest path between two points is a line. In this talk we explore this idea in several different settings. First, we apply this idea to finding the shortest path connecting four points. Then we move this idea up a dimension and look at a few equivalent ideas in terms of surfaces in 3-dimensional space. Surprisingly, these first two settings are connected through soap films that result when a wire frame is dipped into soap solution. We use a hands-on approach to look at the geometry of some specific soap films and "minimal surfaces". (Received August 20, 2014)

1106-E1-908 **Igor V. Minevich*** (igor.minevich@bc.edu), Mathematics Department, Carney Hall 228, 140 Commonwealth Avenue, Chestnut Hill, MA 02467-3806. *Teaching with a Smile.*

I have found that using short puzzles and a research project can help students understand the true art of mathematics and overall have a much more positive experience in a calculus class. We will discuss some of the puzzles and projects that can be used and the advantages and challenges of using them. We will also discuss topics that can be included in a class (without seriously affecting lecture time) which can help students understand the breadth and beauty of mathematics. (Received September 08, 2014)

1106-E1-1410 **Philip Joseph Lombardo*** (plombardo@sjcny.edu). *Music and the Symmetry Group of the Dodecagon.* Preliminary report.

In this presentation, we identify the vertices of a Dodecagon with the 12 pitch-classes of musical notes. Since the dihedral group D_{12} acts on the Dodecagon as rotations or reflections, we can explore the effect of these actions on the identified pitch-classes. The relationship established begs the question, can we use group actions to write music? (Received September 12, 2014)

1106-E1-1642 **Robert R Rogers*** (robert.rogers@fredonia.edu), Dept. of Mathematical Sciences, SUNY Fredonia, Fredonia, NY 14063. *Connecting STE to M.*

The author will present real world applications of Mathematics to Science, Technology, and Engineering. The author will demonstrate how he uses these in a literacy class for pre-service mathematics teachers and in outreach presentations in both middle school and high school settings. Some of the possible topics include relating: nano-polyhedra to chemistry, prime numbers to encryption, divisibility to check digit schemes, parabolas to spin casting telescope lenses, ellipses to lithotripsy and quantum computing, fractals to data compression, origami to medical and industrial uses, complex numbers to aerodynamics. The author will make available any requested assignments or powerpoints. (Received September 14, 2014)

1106-E1-1940 **Yevgeniy V Galperin*** (egalperin@esu.edu), 200 Prospect St., East Stroudsburg, PA 18301. *Applications of Derivatives to Image Processing within a Calculus Course.*

We discuss how working out several derivative-based edge detection methods (the 2x2 Roberts operator, the Prewitt and Sobel kernels, and the Laplacian edge detector) helps students get new insights into the definition of the derivative. We also discuss applications of basic differential calculus to modern wavelet methods of image compression that are accessible to first-year calculus students. (Received September 15, 2014)

1106-E1-1955 **Tamaraa B Veenstr*** (tamara_veenstra@redlands.edu) and **sarah-marie belcastro** (smbelcas@toroidalsnark.net). *Investigating the mathematics of folding regular-polygon-base boxes.* Preliminary report.

Folding is a popular and currently well-funded area of research in the sciences and engineering, and of course mathematics underpins all of this work. We have created materials for a collection of activities for exploring mathematical folding suitable for high-school students. The process of folding boxes from crease patterns engages students and makes the mathematics of the construction intriguing. This presentation will focus on a two-class-period activity set particularly appropriate for calculus students. In the first class period, students fold four different boxes from crease pattern handouts—a downloadable video demonstrates the crucial steps of box assembly—and generalize to create an octagon-based box crease pattern. In the second class period, students design a crease pattern for an n-gonal-base box and explore the trigonometry of the crease pattern in the limit as n increases. These activities allow students to build on high school mathematics material (geometry, trigonometry and limits) to develop their mathematical reasoning skills and see an interesting and unusual application of mathematics. (Received September 15, 2014)

1106-E1-2085 **sarah-marie belcastro*** (director@mathily.org). *Spanning and weighted spanning trees: a different kind of optimization.*

While some high-school students have access to discrete mathematics courses or experience introductions to graph theory, they rarely encounter explicit connections to real-world applications thereof. In this presentation, we describe an introduction to spanning trees and then weighted spanning trees (and their applications!) via structured inquiry. This topic exhibits a different kind of optimization than presented in calculus. The activity is designed to take AP Calculus students a single class period, and has been previously used with high-school students in enrichment settings and beginning college students in a classroom setting.

An AP Calculus supplemental activity should not depend on the the depth of knowledge of the teacher on the particular topic, and the delivery should be flexible enough to accommodate a variety of personal and teaching styles. We therefore provide a guide to the mathematics along with tips on likely student difficulties and a selection of presentation suggestions. Additional supporting materials are an introductory short video, a student worksheet, a concluding video that points toward further exploration, and an extra worksheet with extension questions and a short list of resources. (Received September 15, 2014)

1106-E1-2521 **David M Strong*** (david.strong@pepperdine.edu). *Helping students see beyond Calculus.*

As the first talk in this inaugural session of Helping Students See Beyond Calculus (and with the hopes that there will additional work done and presentations given at future sessions in subsequent Joint Meetings), I will discuss what our larger goals and hopes are for exposing more high school and beginning university students to a variety of mathematical ideas and how this session fits into this larger goal. (Received September 16, 2014)

1106-E1-2524 **David M Strong*** (david.strong@pepperdine.edu). *An introduction to Linear Algebra.*

I will present a condensed version of a self-contained presentation that high school faculty can download and present to their students to pique their interest in studying mathematics in college. The topic I am focusing on in this presentation is Linear Algebra, including several of the interesting, but sufficiently simple for an introductory presentation, applications of Linear Algebra. (Received September 16, 2014)

1106-E1-2704 **Annela R Kelly*** (a3kelly@bridgew.edu). *Systems of Equations as Matrices and Hill Cipher.*

The talk will discuss how to solve systems of linear equations by writing these in the matrix form Ax=b and applying inverse of A (an online applet will be included). Next, the fascinating idea of using matrices in ciphers will be introduced. Finally, a worksheet for the students with Hill cipher will be presented. (Received September 16, 2014)

Humor and Teaching Mathematics

1106-E5-68 **Guanshen Ren*** (gren@css.edu), CSS, Math Dept, 1200 Kenwood Ave., Duluth, MN 55811. *A Mathematician's "aHa" Moment.*

The title in fact is coming from my abstract algebra class when we discuss left cosets and right cosets. I believe that using humor appropriately in math classes without distraction is an important component for students to learn and enjoy math. In this paper, I show a number of humors related to math, especially to calculus in my classes for the past 20+ years. For Example, based on the movie, I made a slide show of "The Good, the Bad, and the Ugly in Mathematics" to illustrate well-known facts as well as common mistakes in math, and I present it on the first day of my classes. As a matter of fact, students become aware of those facts and common mistakes better than other methods I tried before. I connect left limit and right limit with "Democrats" and "Republicans", and use a "New York bartender" joke to remind students of applying mathematical patterns in a right way. I even "threaten" my students with taking them to Judge Judy if they break the laws of exponents. Students really like these humors and keep asking me for more. Some secondary math education graduates told me that they used similar jokes in their math classes. (Received June 25, 2014)

1106-E5-97 **John C Wierman*** (wierman@jhu.edu), Dept. of Applied Mathematics & Statistics, 100 Whitehead Hall, Johns Hopkins University, Baltimore, MD 21218. *The Class Joke Contest: Encouraging Creativity and Improving Attendance.* Preliminary report.

In each of my classes on probability and stochastic processes, I hold a monthly joke contest. Students are encouraged to submit original jokes relating to the course and its topics. The TAs and I select a few finalists, and the class votes to determine winners, who receive extra credit. In spring 2013, a student photographed me showing a slide displaying a joke, and put it on the internet. For a brief time, it was #1 on the front page of Reddit, and at the end of the year, it was #14 on the BuzzFeed list of "people who absolutely nailed it in 2013." The talk discusses the origin and evolution of the contest, its benefits in increased engagement and improved attendance, and provides some tips for faculty who might want to conduct one in their course. (Received July 14, 2014)

1106-E5-325 **Sarah J Greenwald*** (greenwaldsj@appstate.edu), 121 Bodenheimer Drive, 326 Walker Hall, Boone, NC 28608. *Engaging Students with Mathematical Humor: "The Simpsons," Comics and More.*

We now interrupt this regularly scheduled class for mathematical humor, video, comics, puns and more? Well hopefully we are not actually interrupting our classes, as the best humor in the classroom ties into course content, flows naturally and has an interactive component. For years I have been engaging students (and sharing with teachers) this kind of cartoon humor in the classroom via simpsonsmath.com, coauthored with Andrew Nestler. I have also created my own comic strips for classes like linear algebra. I'll report on long-term study of student responses and the benefits and challenges of using humor in the classroom. I'll also discuss ways to choose from the existing literature or to create your own gags based on best practices. In the process I'll give examples of how I use these in classrooms, from courses for non-majors to those for majors. If space is the final frontier, then what is a subspace? Come see to find out! (Received August 22, 2014)

1106-E5-1292 **Lawrence M. Lesser*** (lesser@utep.edu), Mathematical Sciences Dept., 500 W. University Avenue, El Paso, TX 79968, and **John Weber**. *Research, Resources, and Recommendations for Using Humor/Fun in College Mathematics/Statistics Courses: Lessons Learned from Survey Research and NSF-funded Randomized Experiments and a Case Study.*

Our Nov. 2008 J. of Statistics Education paper gives 20 modalities of fun (e.g., humor, songs, cartoons, and games) and potential benefits, with math songs reviewed in the first author's 2014 J. of Mathematics and the Arts paper. In March 2013 J. of Statistics Education, our survey of (N= 249) college instructors found the genders had similar motivations for using fun, but different hesitations and modality preferences. In https://www.causeweb.org/ecots/ecots14/32/, we discuss our funded (NSF/EHR/DUE 1140690/1141261/1140592) fall 2013 student-randomized experiment that investigated if students randomly selected for exposure to fun inserts (e.g., CAUSEweb.org cartoons or songs) in otherwise conventional self-contained short readings in their LMS (thus removing variable of instructor difference or talent) would experience improved learning (measured by embedded exam questions), attitudes towards statistics (by SATS), and reduced statistics anxiety (by SAM). With songs, students randomized to the fun group got their embedded questions correct an average of 50.0% of the time, compared to 42.3% for the other students (p approx .04). The use of cartoons and quotes did not show any differences between groups on test item performance, nor were there differences on anxiety or attitude. (Received September 11, 2014)

1106-E5-1364 **Tim Chartier*** (tichartier@davidson.edu), Davidson College, Department of Math and CS, P.O. Box 6908, Davidson, NC 28305. *Clowning around with mathematical ideas.*

Clowns often play the role of a prankster and/or buffoon. Both roles can be useful in the teaching of mathematics. Experimentation can play a vital role in exploring and discovering mathematical ideas. A clown can plod through mathematics and discover. Moreover, a clown traditionally succeeds through failure – an important lesson for the mathematical classroom. In this talk, Tim Chartier, a professionally-trained mime, will discuss aspects of clowning used in his mime show, Mime-matics. Further, he will give examples of mathematical ideas introduced silently with clowning in performances in Japan and South Korea. (Received September 12, 2014)

1106-E5-1454 **Leigh Atkinson*** (atkinson@unca.edu). *Unrealistic Word Problems, and Other Stupid Math jokes or Take My Dept Chair . . . Please.*

On exams and in lectures, humor can be used to emphasize what is important, to make what is important memorable, to lighten the mood of a classroom, and to make mathematics seem more human than Vulcan. The presenter has tried for 25 years to be funny in class, with what success the audience for this talk will be able to judge; he will present examples of what has seemed to work, on the board and on exams, along with some thoughts on the limitations of humor as an aid to math education. (Received September 13, 2014)

1106-E5-1474 **Katarzyna Kowal*** (kkowal@ramapo.edu), Ramapo College of New Jersey, School of TAS, 505 Ramapo Valley Road, Mahwah, NJ 07430. *Enhancing learning in a proof writing course.* Preliminary report.

In this paper the author will describe how math can be combined with humor to enhance learning in a proof writing course, using techniques that have been tested in the classroom. This 200-level course is an introduction to the abstract level of mathematics (after years of mostly computational math courses which students take from elementary through early college education). The jump from the "computational" to the "abstract" produces anxiety in many students, so it is important, particularly in this course, to counteract this anxiety with the use of humor and not by sacrificing the mathematical rigor of the course. Some examples of connecting humor to specific course content will be shown. One of the course goals is to provide students with perspectives on the nature and relevance of mathematics. Such perspectives will be discussed along with analogies and math jokes that effectively reveal the nature and relevance of mathematics. We'll see that just like a picture can be worth a thousand words, some math jokes can be worth a thousand words when it comes to revealing the nature of mathematics. The author will also describe the effects that the use of humor in this course has on student learning through an analysis of student evaluations, exams, and other results. (Received September 13, 2014)

1106-E5-1580 **Randall E Cone*** (conere@vmi.edu), 410 Mallory Hall, VMI, Letcher Avenue, Lexington, VA 24450. *Jive Talkin', Math Walkin'.*

There once was this friend of mine, "Funny Six" was the name she'd go by. The Greeks dubbed her "Hexa", But later, just to vex ya', The Romans instead called her "Vi"... (Received September 14, 2014)

1106-E5-1710 **Thomas Drucker*** (druckert@uww.edu), Department of Mathematics, University of Wisconsin–Whitewater, 800 West Main Street, Whitewater, WI 53190. *True Nature to Advantage Dressed.*

Humor is an essential part of creating an environment in which students can learn, in mathematics and other disciplines. There are many examples of anecdotes from the history of mathematics which can elicit a smile (or perhaps a groan) from students in the room. Caution is needed, however, in not reinforcing stereotypes about mathematics and mathematicians. This talk illustrates some of the hazards in ill-chosen jests without giving up on the encouragement to promote mathematics with laughter rather than tears. (Received September 15, 2014)

1106-E5-1788 **Dawn Archey*** (archeyde@udmercy.edu), 4001 W. McNichols Rd, Detroit, MI 48221. *Comic strips as semi-authentic applied problems.*

The author frequently includes problems based on comic strips on her exams in math courses from 100 level to 400 level. This talk will focus on examples of problems the author has used and how the author prepares her students to succeed at these problems. Some comic strip problems are simple questions using lower order thinking skills such as performing a computation suggested in the comic strip. Other problems are deeper questions requiring students to explain how a concept was used or misused. For example, in xkcd.com/605/ the male character explains to the female character that since she had zero husbands yesterday and one husband today that by late next month she will have several dozen husbands. The author asks the students to explain the comic using their knowledge from the class, with the desired response being a comment about the dangers of extrapolating far outside the data set. Exam questions based on comic strips offers an intermediate level between contrived textbook story problems and the depth of a truly authentic applied problem. (Received September 15, 2014)

1106-E5-2028 **Janine E Janoski***, janinejanoski@kings.edu. *The Art of Themed Exams.*

What do Tyrion Lannister, Walter White, and Daryl Dixon have in common? They are all characters on TV shows that college students love. What do they have to do with mathematics? They make fun topics to write about on an exam.

In this talk, we will discuss the ups and downs of using pop culture references on exams. We will show you some examples of themed problems, give you tips on things to consider if you want try theming an exam, and discuss student reactions/feedback. (Received September 15, 2014)

1106-E5-2150 **sarah-marie belcastro** (smbelcas@toroidalsnark.net) and **Thomas C Hull*** (thull@wne.edu). *Teaching abstraction via wackadoodle scenarios.*

The presenters use goofiness in their teaching not only to keep student focus, but also to help students learn to abstract the underlying mathematics from a problem setup and help students learn to translate between formal mathematical and conversational statements. Our presentation will both describe and demonstrate the different ways in which we teach humorously and the instructional commonalities we share, with particular reference to the abstraction and translation goals. To a certain extent, implementation of levity must be personal; thus, we will also give examples of how several of our colleagues at MathILy (a summer program at which we teach) interpret these same ideals. Here are some teasers: What does a picky eater's menu for Thanksgiving dinner 2013 have to do with Hall's Matching Theorem? Into how many pieces does the Staff of Ra lasercut a hypertiramisu? Given Paul Krugman's seminal research on interstellar travel, we need to know—how few wormholes can you activate and still connect all your space stations? (Received September 15, 2014)

1106-E5-2315 **Erika L. Ward*** (eward1@ju.edu). *Peanut Butter and Jelly Guy: Audience, Correctness, and Revision in a Proofs Course.*

In Mathematics and Reasoning, the introduction to proofs course at Jacksonville University, I told my students a story about how difficult it can be to write precise directions in English as a way to discuss how and why the language of Mathematics allows us to be more precise.

Unexpectedly, the students adopted a character from the story, and named him Peanut Butter and Jelly Guy. His presence in the classroom allowed the students and I to change their discussion of the entire process of proof writing in profound ways. He added distance and levity to discussions of audience, correctness, and revision – topics that can be difficult for students to internalize. Because PBJ Guy was a bit ridiculous and silly, he enabled students to take themselves less seriously and to laugh at themselves. This made them better able to figure out how to give and take criticism usefully, and thus to become better writers and mathematicians. (Received September 16, 2014)

1106-E5-2630 **Phong Le*** (ple@niagara.edu), Dunleavy Hall Rm #333, Mathematics Department, Niagara University, NY 14109. *Using Science Fiction and Impossible Situations in Mathematical Modeling.*

Somehow, teaching students to model real world behavior using mathematics always seems to involve rabbits that never die, geometrically similar water bottles, an unusual availability of frictionless surfaces and are often set on a desert island. Instead we can use scenarios taken from works of fiction and creative-nonfiction in the hopes of improving engagement and promoting curiosity. In particular, novels such as Andy Weir's, *The Martian* and Randall Muroe's recent book of hypotheticals, *What if? Serious Scientific Answers to Absurd Hypothetical Scenarios*, provide entertaining and interesting applications of deep mathematical thinking and problem solving. In this talk we describe our experiences deriving content from these works as well as student reaction to these challenging, often open-ended situations. (Received September 16, 2014)

1106-E5-2651 **Cesar Martinez-Garza*** (cxm58@psu.edu), Penn State Berks, Tulpehocken Road, P.O. Box 7009, Reading, PA 19610. *Applied Humor in Undergraduate Calculus Courses.* Preliminary report.

Everyone know a joke or two involving an engineer, a physicist, and a mathematician. Whether the punch line involves spherical chickens, minimal fences around the universe, or deranged exponentials, the audience needs different levels of competence in Mathematics and/or Physics to appreciate the humor in the joke. An interesting challenge is to address these same jokes in a classroom setting following the explanation of the theorem or concept upon which they are based. Then, the Intermediate Value Theorem comes to life when the engineer, physicist, and mathematician roommates face a fire in their own kitchen, or when the integral of e^x reveals that a deranged mathematician in an asylum is effectively invulnerable.

This presentation will encompass many of the connections that the speaker has found to be quite effective in communicating Differential and Integral Calculus to undergraduate students. (Received September 16, 2014)

Infusing Quantitative Literacy in Mathematics and Nonmathematics Courses

1106-F5-51 **Samuel Luke Tunstall*** (tunstallsl@appstate.edu). *The Efficacy of Projects and Discussion Boards in Increasing Quantitative Literacy in an Online College Algebra Course.* Preliminary report.

In this talk, I will discuss my efforts to infuse quantitative literacy in an online version of College Algebra, the first online math course for undergraduates at Appalachian State University. This course will be taught in the Fall 2014 semester. At Appalachian State, College Algebra is one of many courses that fulfill the QL requirement. It is taught almost exclusively by graduate students, and is a terminal course for many who take it. This research relates to the concern that – in light of course content and traditional teaching methods – students leave College Algebra with very few gains in QL. An online platform provides a unique means of engaging students in quantitative discussions and research. My online course includes a number of news discussions and data-driven projects; these "sneak" QL into topics which are typically cut-and-dried for teachers and students. The projects also promote the development of technology literacy, as students use Excel and even create their own website. Using the QLRA (developed by the National Numeracy Network), I will assess whether the online students have significant gains compared to those taught in traditional sections of the course. As a graduate student, I look forward to providing a unique perspective on this important topic. (Received August 04, 2014)

1106-F5-358 **Victor I Piercey*** (piercev1@ferris.edu), Department of Mathematics, 820 Campus Drive, ASC 2021, Big Rapids, MI 49307. *Quantitative Ethics: What Is It and Why Is It Important?* Preliminary report.

One element of quantitative literacy and quantitative reasoning involves ethical questions. How do you choose and phrase quantitative questions? How do you communicate results? What happens if your results don't match the desires of a client? Quantitative literacy courses typically address these questions from the point of view of students who will consume mathematical information. This means that they will have to be aware of potential misleading statements that they read or hear. But what about producers of mathematical information, such as business professionals or journalists?

In this talk, I will share how I have incorporated a mathematical information producer's perspective on these issues into a quantitative reasoning course for business students. I will also share case studies from my course that demonstrate the consequences of quantitatively unethical behavior. (Received August 25, 2014)

1106-F5-916 **Robert G Root*** (robroot@lafayette.edu), Math Dept, Lafayette College, Easton, PA 18042. *Introducing Quantitative Literacy in Writing Course using the Ultimatum Game.*

When teaching a writing course on Quantitative Literacy (QL) and Social Justice, the author has found the ultimatum game a useful tool for demonstrating both concepts. This presentation will introduce the ultimatum game and just enough game theory to analyze it. An overview of the way students play the game in class demonstrates that most do not conform their play to theory. Worse, typically conforming players are penalized. Comparing students' play with the play of subjects from around the world suggests that this penalty is widely imposed. We consider the learning opportunities available in this lesson as examples of quantitative literacy, and as demonstrations of the practical implications of QL as a tool for making decisions and persuading others. (Received September 08, 2014)

1106-F5-947 **David G Taylor*** (taylor@roanoke.edu), MCSP Department, Roanoke College, 221 College Lane, Salem, VA 24153. *Combining Hands-On Probability with Calculations: Enhancing Quantitative Literacy through Textbook and Course Design.*

Roanoke College has a three-week, intensive learning term during the month of May each year; the development of my course, "The Mathematics of Games," led to a class that meets for three hours a day, five days a week, during our term. On a typical day, students first play a game guided by specific events to watch for and keep track of. In groups, students match what they see with some elementary and immediate calculations that give the "true" probability of those events. This process repeats, with occasional 15-minute discussions led by the instructor that further the students' knowledge of particular chance events. By the end of the course, students have developed a better intuition for probability along with an enhanced understanding and appreciation of quantitative literacy in today's world. More recently, I have developed a new textbook for this course that incorporates a model that puts each game and its rules first, followed by interesting questions about that particular game, with the development of a mathematical concept immediately after to address those questions. Students have appreciated this approach as it helps them see that being quantitatively literate in today's world can help them understand and answer a wide variety of interesting questions. (Received September 09, 2014)

1106-F5-1812 **Hansun To*** (hto1@worcester.edu), 486 Chandler Street, Math Department, Worcester State University, Worcester, MA 01602, and **Maria Fung** and **Janice Yee**. *Developing Quantitative Literacy across the Liberal Arts Curriculum (QLAC) at Worcester State University.* Preliminary report.

A three-member faculty learning community at Worcester State University (sponsored by the Davis Foundation) presented examples of infusing quantitative literacy across the liberal arts curriculum. Each of the three faculty members worked with member s of the humanities and social science departments to develop quantitative literacy units for a variety of courses. All these courses receive the Quantitative Learning designation. We share some of the activities developed as a result of this process. (Received September 15, 2014)

1106-F5-1975 **Michael P Saclolo*** (mikeps@stedwards.edu), 3001 South Congress Avenue, Austin, TX 78704. *Using an online interactive tool in an assignment on percent.* Preliminary report.

We describe an assignment implemented in a mathematics course, where one of the goals is to develop a student's capacity to process and interpret quantitative information. The assignment aims to hone a student's understanding and interpretation of percentages as well as train the student to use simple mathematical techniques to put quantities in perspective. The assignment relies on an online interactive tool that enables the user to obtain information and make comparisons about income pertaining to different geographical regions in the United States and to various occupations. (Received September 15, 2014)

1106-F5-2290 **Cristina Gomez*** (cgomez@ithaca.edu), 953 Danby Road, Ithaca, NY 14850. *Quantitative Literacy for Education Majors.*

The use of data in education in recent years has grown rapidly. Different stakeholders have been asked to use data for different purposes–teachers to drive decisions about teaching, principals to make decisions about teacher quality, and school-districts to study the achievement gap. Most preparation programs for teachers do not include any training for these tasks. Our institution, a small liberal arts college, has a new core curriculum initiative that includes a Quantitative Literacy component for all students. I have designed a course, Numbers in Education, to fulfill this requirement for students completing a teaching option. The course is divided in three parts, each addressing one of aspect of the use of data in education. The first part focuses on studying data related to the achievement gap, the second on the use of quantitative research results in education, and the last on the use of data in classroom assessment. We use a variety of resource–ready available and up to date databases (NCES, NAEP), videos and podcast from the web, and scholarly journal articles and newspaper reports. The classroom activities focus on making sense of numbers, interpreting graphical representations of data, and connecting these to the implications for schools and, ultimate, for students. (Received September 16, 2014)

1106-F5-2360 **Teresa D Magnus*** (tmagnus@rivier.edu), Dept. of Mathematics and Computer Science, Rivier University, 420 S. Main Street, Nashua, NH 03060. *Exploring Debt through Spreadsheets, Graphs, and Functions.* Preliminary report.

A Mathematical Problem Solving and Modeling course presents an ideal opportunity to expose mathematics majors and minors to quantitative literacy. While students may be familiar with the formulas for computing savings and debt at a given time t, working with Excel enables them to view what happens month by month to the account both numerically and graphically. The effects of various parameters become readily apparent. Following the lab, students apply their knowledge of functions and calculus as they explore the development of closed formulas. (Received September 16, 2014)

1106-F5-2362 **Cinnamon Hillyard*** (chillyard@uwb.edu), Bothell, WA 98011, and **Milagros Loreto**. *Quantway: Using Quantitative Reasoning to Teach Developmental Math to College Students.*

The Carnegie Foundation developed a quantitative reasoning course, Quantway, to address the growing need for getting more students to and through their college mathematics requirements. Quantway is commonly offered as an alternative to Algebra 1 and Algebra 2 at more than a dozen colleges. Over 2000 students have successfully completed Quantway nationwide. We will talk about the success rates of the course, how students performed in their subsequent math course, and the predictors of this success. We will also share the successes and challenges of faculty in delivering a developmental mathematics curriculum through a quantitative reasoning lens. (Received September 16, 2014)

1106-F5-2508 **Van Herd*** (herd@austin.utexas.edu), College of Undergraduate Studies, University of Texas at Austin, Austin, TX 78712. *ASPIRE: Quantitative Literacy, Historical, Women's, and Gender Studies Courses at the University of Texas.*

ASPIRE is a grant-based program to encourage women to enter the mathematical and scientific disciplines that integrates women's and gender studies into the fabric of its curriculum. Writing from his perspective as a mathematics instructor who also teaches History of Mathematics and History of Science courses, and who developed, implemented, and taught a Gender and Science course sequence for Women's and Gender Studies under the aegis of ASPIRE, the author will present his experiences, as well as lessons learned and data gathered from incorporating quantitative literacy into these courses at the University of Texas at Austin under a dean's initiative.

The immediate context of this presentation of the Texas model is the desire on the parts of the Department of History and the Women's and Gender Studies Program to offer more mathematics, science, and quantitative reasoning in their course offerings, thus affording their respective majors the opportunity to meet Quantitative Reasoning requirements in a creative and deeply educative manner. (Received September 16, 2014)

1106-F5-2559 **Christopher S Shaw*** (cshaw@colum.edu), Department of Science & Mathematics, Columbia College Chicago, 600 S Michigan Ave, Chicago, IL 60605. *The Unsuspecting Analyst: Mathematics That Needs No Introduction.*

Confronting a new topic in a traditional mathematics class often requires an array of new definitions and techniques, all of which must be introduced before students can begin to work on the material in that topic. Spending time covering definitions before work can begin is not ideal in a typical college-level Quantitative Literacy course, where the audience may be unwilling to become invested in the material. Inquiry-Based Learning is a natural pedagogical response to this challenge, but it comes with its own challenges: in particular, the nontraditional nature of an IBL classroom makes it difficult to replicate in multi-section courses.

This talk describes the author's continuing quest to develop a multi-section Quantitative Literacy course influenced by IBL philosophy, where lists of definitions are kept to a minimum and student participation is maximized. The key element to this quest has been developing problems that can be read, understood, and even attempted, without any prior formalization; these problems then lead naturally to the development of formal definitions. In particular, we present several modules on problem-solving that have been successful at engendering enthusiastic learning in the classroom. (Received September 16, 2014)

1106-F5-2563 **Andrew J Miller*** (andrew.miller@belmont.edu). *Reacting to the Past in a Mathematics Classroom.* Preliminary report.

"Reacting to the Past" is a program that develops and disseminates immersive simulation games that invite students to take on roles from history. In Fall 2013, I ran one of these games, *Ways and Means, 1935*, in my introductory mathematics course. *Ways and Means* was developed by John Curran, Mark Higbee, Russell D. Jones, and Andrew Ross to develop quantitative literacy and argumentation skills by having students re-enact the 1935 debates about the Social Security Act. I will introduce the audience to the game, discuss my experiences with it, and pass on some tips for those interested in running the game in their classes. (Received September 16, 2014)

1106-F5-2672 **Catherine L. Crockett*** (catherinecrockett@pointloma.edu), 3900 Lomaland Drive, San Diego, CA 92106, and **Jesus Jimenez** and **Ryan Botts**. *The impact of a hybrid course format on student learning and attitudes in a Quantitative Literacy Course.* Preliminary report.

With the latest changes in the landscape of higher education and advances in technology, there is an interest in broadening the role of technology in student instruction and learning. For more than a decade, at Point Loma Nazarene University, we have taught a general education quantitative literacy (QL) course using the face-to-face mode of instruction, i.e. traditional class format. We recently changed our QL course instruction format from a traditional to a hybrid one. Here we will report on a preliminary assessment of the impact of changing instruction mode on student learning and attitudinal data. (Received September 16, 2014)

1106-F5-2691 **Kathleen D. Lopez***, klopez@louisiana.edu, and **Melissa G. Myers**, mgmyers@louisiana.edu. *A Freshman Quantitative Reasoning Course at the University of Louisiana at Lafayette.* Preliminary report.

Quantitative Reasoning for Life is a new course for freshman in majoring in non-technical fields at UL Lafayette. Course philosophy, content, sample activities, and assessment will be discussed. (Received September 16, 2014)

1106-F5-2784 **Chris Oehrlein*** (coehrlein@occc.edu). *Experimenting with Quantitative Literacy Activities in a Three-Credit College Success Course.* Preliminary report.

Oklahoma City Community College offers a three-credit version of its traditional one-credit college success course. Students in the three-credit option typically have placed into Developmental Writing (one step below a first-year composition course) and either Basic Arithmetic or Introductory Algebra. One section of this course was targeted in the Fall 2014 semester as a pilot section that would be taught by a mathematics professor so that the course could spend more time on study skills specific to courses with a significant quantitative and symbolic component and on quantitative critical thinking skills. The college hopes that the redesign of the course will expand these objectives and activities to more, if not all, of the sections. This presentation will report on the impressions of the course instructor and the students about the activities and their effectiveness. (Received September 16, 2014)

Innovative and Effective Ways to Teach Linear Algebra

1106-G1-192 **Dan Seth*** (dseth@wtamu.edu), Mathematics, WTAMU, 2501 4th Avenue, Canyon, TX 79016. *Enhanced student learning and attitudes with weekly MATLAB explorations.* Preliminary report.

The MATLAB program has been integrated into Linear Algebra at WTAMU the past six years. The past three years the class format has been restructured to include a weekly MATLAB exploration/lab. The labs implemented over the past 3 semesters incorporate experience with lab materials used over the past 12+ semesters that have been effective. The labs fit topical coverage of an introductory Linear Algebra course. Students are introduced to MATLAB tools and explore or visualize theories. With the encouragement and technical support of Wiley, the labs have a uniform accessible look with streamlined content. The presentation will illustrate tools developed to visualize linear combinations and span and a lab on visualization of the actions of linear operators. Incorporation of the labs has enhanced learning and improved retention. Assessment of added learning and improved attitudes due to student experience with the labs was completed through pre/post course reflection and feedback surveys. Results will be presented. (Received August 07, 2014)

1106-G1-266 **Paul R. Bouthellier*** (pbouthe@pitt.edu), 504 East Main Street, Titusville, PA 16354. *Visualizing Linear Algebra using the HTML5 Canvas.*

The HTML5 canvas is a workspace that can be added to a web page to perform many of the same features as Flash. However, unlike Flash, which is no longer viewable on many devices, any device which can view web pages with a current browser can view canvas animations and interactive content. The canvas also has the advantages of requiring no extra software, no plug-ins, and hence no extra cost to view or create for it. In order to design for the canvas however, one must understand the concepts of translations, scaling, rotations, skewing, and the composition and inverse of matrix transformations. These are needed to properly place and animate objects on the canvas. Using such matrix transformations to create canvas elements will be illustrated. A project containing an interactive canvas in a web page will then be used to illustrate the concepts of translations, scaling, rotations, homogenous coordinates, and projections for both 2 and 3 dimensional objects. Such tutorials may be viewed on any device-computers, tablets, and mobile phones-which can view a web page. (Received August 17, 2014)

1106-G1-327 **Sarah J Greenwald*** (greenwaldsj@appstate.edu), 121 Bodenheimer Drive, 326 Walker Hall, Department of Mathematics, Boone, NC 28608. *Linear Algebra with the Hand and Eye.* Preliminary report.

Educators have a variety methods available to them to deliver mathematical content and facilitate student engagement and learning. Active investigations that utilize both the hand and the eye help students make connections. This is partially what is behind longstanding methods like asking students to write up their solutions. Heavy use of visual/eye-hand portions in the brains are highlighted on imagining studies during mathematical problem solving tasks. In this manner, kinematic activities are linked to 3-D visual processing and to mathematics. I will showcase two “hand and eye” activities in linear algebra. The first is for students to use their hands plus the desk to form three planes to examine their intersections. The students relate the kinematic experience with graphs in Maple (and turning them) as well as similar examples in real-life, like the corner of a room. Students learn to internalize visualizations and associate them with the corresponding algebra. The second activity is in Moodle, an open source course management system, where I have set up linear algebra resources. There, words that match glossary entries we create are hyperlinked within solutions, discussion forums and more. I’ll discuss evaluations of these methods and student responses. (Received August 22, 2014)

1106-G1-556 **Naima Naheed*** (naheedn@benedict.edu). *Motivating Students for linear algebra by using puzzles.*

Linear algebra has become one of the most useful and powerful fields of mathematics since the last decade, yet students still have trouble seeing the connection between some of the abstract concepts and real world applications. A motivation first, theory second approach could be adopted to stimulate students’ intellectual needs for learning. Two puzzles will be introduced in this talk. Through the first puzzle, students will develop a better understanding of rank, undetermined systems, and consistency in linear algebra. The other puzzle is a gossip network that will help students understand the physical meaning of matrix multiplication. This network is a popular reminiscent of the notion of “six degrees of separation”, which suggest that any two people in the world are connected by a path of acquaintances, whose average length is six. By providing alternative learning activities students’ understanding and retention can be enhanced and improved. (Received September 02, 2014)

1106-G1-1196 **C Ray Rosentrater*** (rosentr@westmont.edu), Westmont College, 955 La Paz Rd., Santa Barbara, CA 93108. *An IBL-influenced Approach to Teaching Linear Algebra.*

There are many flavors of inquiry based learning. This talk will present my experience in a spring 2013 offering of linear algebra that eliminated most lectures but provided more support and direction than the traditional Moore method. I will present examples of the prompts used in developing the theory of projections and will conclude with some reflections on the relative success of this approach in comparison to previous lecture-heavy offerings. (Received September 11, 2014)

1106-G1-1287 **Diana White*** (diana.white@ucdenver.edu). *Use of Just-In-Time-Teaching, Khan Academy Videos, and MyMathLab to Partially Flip a Linear Algebra Course.*

Instructors who teach in a student-centered manner often face a tension between content coverage and student engagement. There are a variety of techniques that can be used to help ease that tension. In this talk, we discuss two aspects of instruction that the author has used while teaching the first undergraduate course in Linear Algebra at her institution. The first involves using MyMathLab and a proficiency exam to move the learning and practice of most computational skills outside of class. The second, arguably more substantive, involves using Just-In-Time-Teaching combined with Khan Academy videos to enhance student learning. (Received September 11, 2014)

1106-G1-1338 **Chad Awtrey*** (cawtrey@elon.edu). *Introducing Galois theory in an introductory linear algebra course.*

The goal of this talk is to describe a computational and inquiry-based activity the speaker has used to introduce linear algebra students to the symmetries of roots of polynomials with rational coefficients. Included are discussions of the following: motivating examples, detailed aspects of the activity, implementation suggestions for Mathematica, and subsequent undergraduate research projects the speaker has mentored related to the topic. (Received September 12, 2014)

1106-G1-1339 **Meghan M De Witt*** (mdewitt@stac.edu). *You can use a matrix to do that?*

We explore various projects used to enrich a introductory linear algebra class. These include animating computer graphics, solving unusual magic squares, and football rankings. (Received September 12, 2014)

1106-G1-1482 **Megan Wawro*** (mwawro@vt.edu), **Michelle Zandieh** and **David Plaxco**. *An instructional sequence for change of basis and eigentheory.*

We present an innovative instructional sequence for an introductory linear algebra course that supports students' reinvention of change of basis, eigentheory, and how they are related through diagonalization. Task 1 builds from students' experience with linear transformations in $\mathbb{R}^2$ to introduce them to the idea of stretch factors and stretch directions and how these create a non-standard coordinate system for $\mathbb{R}^2$. Task 2 has students create matrices that convert between the standard and non-standard coordinate systems and relate these to the stretching transformation of Task 1 to reinvent the equation $PDP^{-1}x = Ax$. In Task 3, students build from their experience with stretch factors and directions to create for themselves ways to determine eigenvalues and eigenvectors given various information about a transformation. In Task 4, students work with examples in $\mathbb{R}^3$ to develop the characteristic equation as a solution technique, as well as connect ideas about eigentheory to their earlier work with change of basis through the idea of diagonalization. We will share information about our project website which contains instructor resources such as examples of student thinking, implementation notes, and homework suggestions for this task sequence. (Received September 13, 2014)

1106-G1-1556 **Philip Joseph Lombardo*** (plombardo@sjcny.edu). *GeoGebra and Linear Algebra.* Preliminary report.

Viewing 2×2 matrices as transformations of $\mathbb{R}^2$ allows us to visualize and explore important topics in linear algebra. In this talk, I present some of these visualizations using the free and accessible program GeoGebra. Topics include the range and kernel of a linear transformation, discovery of eigenvalues, and the connection between determinants and area. Time permitting, I will discuss GeoGebra 5.0 beta, that allows us to explore the same topics in $\mathbb{R}^3$. (Received September 14, 2014)

1106-G1-1970 **Yevgeniy V. Galperin*** (egalperin@esu.edu), 200 Prospect St., East Stroudsburg, PA 18301. *Topics in Linear Algebra through Signal and Image Processing.*

We help the students appreciate the importance of non-commutativity of operators through the proof and a discussion of the classical uncertainty principle. Several topics in linear algebra (such as the Vandermonde Matrix) are introduced within the context of the discrete version of the Uncertainty Principle of Donoho and Stark. We use discrete wavelet transforms as a vehicle to illustrate the convenience of working with partitioned matrices, the importance of orthogonality, and the use of linear independence in proofs. (Received September 15, 2014)

1106-G1-1981 **Greg Stuart Mayer*** (greg.mayer@gatech.edu), School of Mathematics, 686 Cherry Street, The Georgia Institute of Technology, Atlanta, GA 30332. *Collaboration and Community in Fully Online Synchronous Linear Algebra Recitations.* Preliminary report.

This presentation describes the results of an ongoing project, currently in its third year, aimed at introducing web conferencing software into two multi-section synchronous online courses for advanced high school students at The Georgia Institute of Technology, the first of which focuses on linear algebra. The primary goals of this project are to increase enrollment in these courses from high schools that are unable to purchase the necessary equipment to participate in the existing delivery model, and to identify factors that lead to student success in the alternate delivery model that uses web conferencing software. This presentation will focus on recent findings that explore the role of online collaboration and the development on community during linear algebra recitations. Findings are based on results from a (qualitative) content analysis of discussions held during recitations, as well as student interview and survey data. Results will be presented that compare how interaction patterns 1) vary across different learning activities, including collaborative group work, and 2) differ between students who have no peers at their school in this program to those students who do. (Received September 15, 2014)

1106-G1-2077 **Jeremy Case*** (jrcase@taylor.edu), 236 W. Reade Ave., Upland, IN 46989. *My Favorite MAA Articles for Linear Algebra.* Preliminary report.

Linear Algebra has many wonderful applications which are not always explored in depth in textbooks. Furthermore, a Linear Algebra course often services not just mathematics majors but those in other areas such as education, economics, and computer science. Assigning journal articles can be a way of meeting these diverse needs, but beginning undergraduates often have difficulty reading them. This talk will not just provide a list of favorite MAA articles but will suggest strategies for incorporating journal articles into a Linear Algebra class. (Received September 15, 2014)

1106-G1-2216 **James D. Factor*** (james.factor@alverno.edu) and **Susan Pustejovsky** (susan.pustejovsky@alverno.edu). *Interleaving Connections of Difficult 2D and 3D Linear Algebra Concepts using Interactive Explorative GeoGebra Applets.* Preliminary report.

In this presentation, an interactive GeoGebra applet will be used to show the interleaved connections between concepts such as change of basis, linear dependence, independence, linear combinations, and at the same time incorporate the meaning of their algebraic, graphic, and numeric representations. By interleaving 2D and 3D concepts, it will be shown that a fluent and natural understanding of the mathematics can be achieved. In this way, ideas and the meanings of symbolic manipulation that are often difficult to explain and understand can become clear.

As part of the project **Transforming Linear Algebra Education with GeoGebra Applets (NSF TUES Grant DUE-1141045)**, 12 packages, including 2D/3D interactive applets, with instructional modules, activities, and applications will be produced for a first course. Our curriculum goal is to support student mathematical growth in becoming harmonic thinkers, i.e. mathematical problem solvers that can easily move between and among various geometric, analytic, and numeric representations in the process of understanding and solving linear algebra problems.

More detailed information is given at the MAA/NSF Poster Session. Future plans include mini-courses on classroom use and a website containing all packages. (Received September 16, 2014)

1106-G1-2280 **Shane Macnamara*** (shmacnamara@davidson.edu) and **Tim Chartier**. *Exploring $Ax = b$ in a DavidsonX MOOC.* Preliminary report.

DavidsonX is a Davidson College partnership with edX, a non-profit enterprise founded by Harvard and MIT. Davidson is one of the first liberal arts colleges to collaborate with edX on the Consortium platform, which is now comprised of 30 global educational institutions. In February of 2015, Dr. Tim Chartier will lead a MOOC on applications of linear algebra that focuses largely on topics in computer graphics and data mining. An important piece of the MOOC will be interactive web applications designed for student exploration and discovery. This talk will give examples of these applications in both computer graphics and data analysis. (Received September 16, 2014)

1106-G1-2316 **John Hannah**, **Sepideh Stewart*** (sstewart@math.ou.edu) and **Michael Thomas**. *Teaching Linear Algebra in the embodied, symbolic and formal worlds of mathematical thinking: Is there a preferred order?*

In this research project, using Tall's three worlds of mathematical thinking as a theoretical framework, students were taught fundamental linear algebra concepts using each of the embodied, symbolic and formal dimensions. By varying the order in which these approaches were used in each topic we investigated students' perceptions of the combinations and their potential for understanding and learning. The results show that students seem to react positively to symbolic examples and embodied ideas but there is little effect overall of order on understanding. (Received September 16, 2014)

1106-G1-2536 **Spencer Payton***, Department of Mathematics, PO Box 643113, Neill 103, Washington State University, Pullman, WA 99163. *Unifying Concepts in the Introductory Linear Algebra Course.*

The introductory linear algebra course provides many unique challenges to undergraduate students. With so many new concepts and definitions, students often struggle to see the inherent connections between these concepts. In this action research study, I attempted to discover alternative ways of presenting these connections to undergraduates. I observed and collected data from several introductory linear algebra classes, including my own. Data was collected from student responses to worksheets, midterm examinations, and interviews. In my presentation of the material to my class, I attempted to illustrate connections through solution sets of matrix equations. This presentation led to several students displaying what I describe as a linear systematic concept image. These students seemed more able to see and make connections between linear algebraic concepts. (Received September 16, 2014)

1106-G1-2660 **J D Fortin*** (dfortin@jwu.edu), J. D. Fortin, 801 West Trade St., Johnson & Wales University, Charlotte, NC 28202. *How Do Badly Conditioned Systems Misbehave?*

Badly conditioned linear systems are characterized by large condition numbers and by the fact that small changes in the coefficients (e.g., rounding) can result in significant changes to the solution. What is the tie-in between condition number and sensitivity to changes? The objective is an explanation that ties in closely with the process of solving linear equations and that students can understand.

A badly conditioned system is introduced, and technology (e.g., Matlab) is applied for the singular value decomposition. The linear system is uncoupled via the singular vectors, and technology is employed to assess sensitivity to small perturbations of the uncoupled system. Results of systematic perturbations are given. The uncoupled system allows easy computational and algebraic solutions. The latter are employed to explain large and small responses to small perturbations in terms of the singular values and to highlight the role of the singular vectors as directions of change. (Received September 16, 2014)

1106-G1-2893 **Michelle L Ghrist*** (michelle.ghrist@usafa.edu). *Magic Squares and Other Explorations in Linear Algebra.*

When I taught a proof-based Linear Algebra course for the first time last year, I encouraged my students to deeply ponder the ideas and ask hard questions, fully admitting that I did not have all of the answers. Several interesting side ventures arose from student questions; in this talk, I discuss some of these quests, how I incorporated them into the classroom, and how the use of technology facilitated the discovery process. Topics include how a survey of commuting matrices arose from a discussion of elementary matrices and how an exploration of magic squares arose from a discussion of vector spaces. (Received September 17, 2014)

Inquiry-Based Learning in the First-Year and Second-Year Courses

1106-G5-357 **Victor I Piercey*** (piercev1@ferris.edu), Mathematics Department, 820 Campus Drive, ASC 2021, Big Rapids, MI 49307. *Inquiry-Based Learning in a Quantitative Reasoning Course for Business Students.* Preliminary report.

"Just tell me how to solve the problem!" Sound familiar? Promoting buy-in to inquiry-based learning is particularly challenging for college freshmen who are not mathematics majors. In this talk, I will share my approach to inquiry in a quantitative reasoning course for business students. In particular, I will address the interaction between curricular materials and inquiry-based pedagogy, my strategies for promoting and sustaining student buy-in, and how I scaffold the level of inquiry throughout the course. In addition, I will share data concerning the impact on math anxiety and beliefs. (Received August 25, 2014)

1106-G5-408 **A. S. Eljhader*** (a.elkhader@northern.edu), Dept. of Sciences & Mathematics, Aberdeen, SD 57401. *Inquiry-Based Instruction in a Standard Differential Equations Course for Math Education Major.*

This study describes a suitable use of inquiry-based mathematics instruction in a standard elementary differential equations course. Students, who are math education majors, are introduced to linear and nonlinear systems of ordinary differential equations at the early stages of the course. Students, who worked in groups, were engaged in developing locally relevant models such as urban/rural interactions, mosquito growth, seasonal hunting and fishing, and others. Computer technology such as Maple was used to analyze the models, and to explore the various possible outcomes as parameters change. Students' attitude toward the pedagogy used in the course as well as other assessment tools will be shared. (Received August 27, 2014)

1106-G5-949 **Thomas E Cooper*** (thomas.cooper@ung.edu), 82 College Circle, Dahlonega, GA 30597, and **Brad Bailey** and **John E Holliday**. *A Modified Moore Method in Precalculus: Achievement, Attitudes, and Beliefs.*

The presenters have completed a two-year quasi-experimental study of the use of a Modified Moore Method (MMM) in Precalculus. This study included six traditional lecture classes and seven MMM classes taught by three instructors. Both quantitative and qualitative data was analyzed to investigate achievement as well as attitudes and beliefs. In this talk, we will present a brief summary of our results with a particular focus on an "Openness to Inquiry Based Learning" survey that we have developed for assessing students' preferences for Student-Centered or Teacher-Centered instruction. Students who score higher on this survey, tended to perform better on the final exam; indicating that a key element to success in an MMM course may be the students willingness to participate. (Received September 09, 2014)

1106-G5-993 **W. Ted Mahavier*** (ted.mahavier@lamar.edu). *IBL Course Notes for Calculus I, II, & III.*

Calculus can be a fertile recruiting ground for majors. When teaching calculus early in my career, I would see students who sought a deeper understanding perform poorly on rote exams. Potential mathematicians were being lost because I was rewarding rote performance over mathematical inquiry! This talk addresses a set of calculus notes that engages students from the first day by having them solve problems and discuss solutions with the class. Started as an NSF project fourteen years ago, these notes have been used in one form or another at dozens of schools including: Cal Lutheran, College of Idaho, Drury, Holy Cross, Lamar, Lewis & Clark, NAU, SUNY Potsdam, and USNA. These notes are freely available, problem-based, include practice sets and cover all of Calculus I-III. (Received September 09, 2014)

1106-G5-1087 **Matt Boelkins*** (boelkinm@gvsu.edu), C2508 Mackinac Hall, Grand Valley State University, Allendale, MI 49428. *Small-group activities instead of examples: an inquiry-based approach to calculus.*

Historically, calculus texts and calculus instruction have presented students a large number of completed examples. Often, students then solve related problems by emulating work done in the examples. In an effort to instead have students build their own intuition, think more independently, and discover key ideas themselves, I have developed a large (and freely available) collection of activities that engage students in learning calculus in a more inquiry-based style. In this talk, I will share some sample activities, discuss the structure of a typical class meeting, and reflect upon student feedback and outcomes with this approach. (Received September 10, 2014)

1106-G5-1277 **Celil Ekici*** (celil.ekici@uvi.edu), RR1 Box 10000, Kingshill, VI 00850-9781, and **Andrew Gard** (andrew.gard@uvi.edu). *Inquiry-Based Learning of Transcendental Functions in Calculus I and II.*

Developing a deep understanding of transcendental functions such as e^x and $\sin x$ should be an essential secondary goal of any calculus sequence. In recent semesters, we have pioneered inquiry-based calculus learning activities engaging students in building a series of polynomials with self-similar derivative structures. While using educational technologies in their explorations, students in peer groups develop their understanding through algebraic, numerical and geometric representations. This discourse facilitates students' construction of the series representations of transcendental functions. Students discover that the problem of their synthesis can be reduced into a sign pattern problem ultimately solved by devising a number whose powers reproduces the pattern. First-semester work culminates in the discovery of the Euler's Formula and paves the way for second-semester applications from the integral standpoint. We will further share our philosophy, techniques and results. (Received September 15, 2014)

1106-G5-1357 **Stephanie L. Fitch*** (sfitch@mst.edu), **Robert P. Roe** (rroe@mst.edu) and **Paul N. Runnion** (prunnion@mst.edu). *Interactive Engagement in Calculus Labs at Missouri S&T.*

Over the course of the past year the Department of Mathematics and Statistics at Missouri University of Science and Technology has undertaken a redesign of our three semester calculus sequence. During the Fall 2014 semester we pilot tested elements of this redesign in one section of our Calculus I course with an enrollment of approximately 120 students. One of the components of the redesign is to dramatically increase student engagement during their lab (recitation) section through the use of inquiry-based techniques. This talk will provide an overview of observations and results from the pilot, as well as future plans. (Received September 12, 2014)

1106-G5-1365 **Allison K Henrich*** (henricha@seattleu.edu), Seattle University, 901 12th Ave, PO Box 222000, Seattle, WA 98122. *Daily Student Presentations in Quantitative Reasoning and Calculus.* Preliminary report.

Inquiry-based learning is becoming more and more common in upper-level proofs-based courses. One popular model involves students presenting homework problems at the board while their classmates ask questions, provide suggestions for improvement, and take notes. While this is a useful model for proofs-based courses, can it be beneficial in freshman math courses as well? I firmly believe so. In the last year and a half, I have incorporated daily student presentations into my Quantitative Reasoning courses as well as Calculus I and II, with encouraging results. I will share the details of my methods as well as my reasons for believing that this model promotes student learning. (Received September 12, 2014)

1106-G5-1386 **Brian Johnson*** (bpjohnson@fgcu.edu) and **Katie V. Johnson** (kjohnson@fgcu.edu). *Experiences with Process Oriented Guided Inquiry Learning (POGIL) in a general education mathematics course.* Preliminary report.

We will highlight some of the activities used in a general education math course. Finite Math focuses on problem solving and mathematical reasoning through studying concepts in geometry, set theory, logic, probability, and statistics. Eighteen 75-minute activities were developed and facilitated in four sections of 35 students each over two semesters. The activities were designed specifically for use in a POGIL (Process Oriented Guided Inquiry Learning) classroom. Feedback from students was exceedingly positive, failure rates decreased dramatically, and we will share other anecdotes. (Received September 12, 2014)

1106-G5-1414 **Christine von Renesse*** (cvonrenesse@westfield.ma.edu), **Mairead Greene** and **Paula Shorter**. *Teaching Calculus 1 and 2 using Inquiry.*

We will present an example of how Calculus 1 and 2 can be taught without any lecture, using inquiry-based techniques including small group work and large class discussion. The materials (see www.iblcalculus.com) were developed by Mairead Greene and Paula Shorter at Rockhurst University, MO, and have been used several times at Westfield State University, MA. The goal of the materials is for the students to develop a deep conceptual understanding by engaging them in the process of independently reasoning from concepts and prior knowledge to answer questions, solve problems and develop definitions and theorems. Data and anecdotes provide evidence of the success of this approach. (Received September 12, 2014)

1106-G5-1421 **Catherine Bénéteau**, **Zdeňka Guadarrama**, **Jill E Guerra*** (jill.guerra@uafs.edu) and **Laurie Lenz**. *Effective implementations of POGIL in the Calculus I classroom.*

Process Oriented Guided Inquiry Learning (POGIL) is an instructional strategy that guides students toward the discovery of a particular concept by working in self-managed teams of three or four on specially designed POGIL activities. A POGIL classroom focuses both on the achievement of content knowledge and the development of process skills such as effective communication of mathematical arguments, information processing, critical thinking, teamwork, and metacognition. In this talk we will give examples of POGIL activities used in Calculus I and report data on the effectiveness of POGIL implementation at a variety of institutions. (Received September 12, 2014)

1106-G5-1451 **Mircea Pitici*** (mip7@cornell.edu), P.O. Box 4671, Ithaca, NY 14852. *A Writing Seminar on Mathematical Topics: Changing Views by Considering Perplexing Counterfactual Themes.* Preliminary report.

In this talk I describe the first-year writing seminar I taught at Cornell University for five years. I designed a course unique in content, goals, means, and expectations, aimed mainly at students with a strong background in mathematics (future majors in mathematics, engineering, computer science, sciences). To achieve my proposed ends, chiefly an overhaul in students' general beliefs about mathematics, I asked the students to read selected writings on mathematics, to consider certain surprising possibilities (including counterfactuals), to listen to professional mathematicians invited as guests, to discuss and react to their peers' opinions, and to examine in new light the knowledge of mathematics they have acquired throughout their school career. The course gave students a sense of self-awareness toward personal aspects, choices, and assumptions involved in gaining mathematical experience. Although I prepared this seminar for (and and I taught it to) undergraduates, another good audience for it would be formed by high-school mathematics teachers. (Received September 15, 2014)

1106-G5-1455 **Brian Katz*** (briankatz@augustana.edu). *To $\delta\varepsilon$ or not to $\delta\varepsilon$.*

What is the role of the $\varepsilon - \delta$ definition of a limit in an introductory Calculus course? This definition can overwhelm young students, and yet without it these same students can become frustrated that there is no way to provide solid answers to questions about Calculus. In this talk, I will describe a task that facilitates guided-reinvention of the definition of limit adapted from the work of Michael Oehrtman and other RUME scholars. I will put the task in the context of a course that uses notes by Brian Loft and connect it to the larger inquiry trajectory in these notes. (Received September 13, 2014)

1106-G5-1560 **Brian M. Loft*** (loft@shsu.edu), Dept. of Mathematics and Statistics, SHSU, Huntsville, TX 77341-2206. *Developing a set of IBL course notes for integral calculus: ideas, challenges, and a request for suggestions.* Preliminary report.

There are unique challenges using IBL techniques in a calculus classroom: pressure to cover enough material to prepare students for another course, more students not majoring in mathematics, and large class sizes. These challenges (among others) extend to the development of IBL course notes. While the author has had some success with the creation of a set of notes for differential calculus, another set for integral calculus is proving to be more difficult. A preliminary outline of a set of notes for integral calculus will be discussed, along with the challenges that have been encountered. Suggestions for solutions to these challenges will be solicited. (Received September 14, 2014)

1106-G5-1597 **Helmut Knaust*** (hknaust@utep.edu), Department of Mathematical Sciences, The University of Texas at El Paso, El Paso, TX 79968. *Exploration and Inquiry in an Introductory Course for Mathematics Majors.*

My department is offering an introductory course for Mathematics majors, modeling Mathematics as a laboratory science. The course, based on material developed at Mount Holyoke College, requires only pre-calculus and co-enrollment in Calculus I.

Students in small groups explore several rich mathematical topics on their own. They perform mathematical experiments (with the help of a computer algebra system), formulate, test and refine conjectures, and finally try to prove their conjectures. At the end of each two week laboratory, the student teams write up their findings in a laboratory report. (Received September 14, 2014)

1106-G5-1689 **Milos Savic*** (savic@ou.edu). *Incorporating Social Norms and "Leveling Up" to a Medium-Sized Calculus II Course.* Preliminary report.

Social norms are roughly defined as the "rules of the environment" of the classroom, with the rules either verbally or non-verbally communicated. I aimed to incorporate two main ideas in my Calculus II course: one can "level up" (borrowing a video game phrase) to reach benefits and ultimately a grade in the course, and that the environment is one that is non-judgmental, meaning students cannot judge each other for what they state verbally. This has resulted in many students participating frequently in this Calculus II IBL course (of 35 students), which has, in turn, caused discussion to be fruitful. I elaborate on both ideas in my presentation, noting that the content of the course is non-essential: one can use the two ideas in other courses, specifically in first- and second-year courses. (Received September 15, 2014)

1106-G5-1725 **Silvia Saccon*** (silvia.saccon@utdallas.edu), The University of Texas at Dallas, Richardson, TX 75080. *Engaging calculus students through problem-solving workshops.* Preliminary report.

To foster students' active engagement in their learning and to promote their conceptual understanding of calculus, I started to run my classes as problem-solving workshops. Students experience a full immersion in problem-solving activities by collaborating in small teams at the board on problems designed to build and stretch their conceptual understanding of calculus. Deep engagement in mathematical tasks, combined with immediate feedback through discussions with peers and me, helps students develop their critical reasoning, problem-solving, and communication skills. In this talk, I will describe class structure and activities performed by students, discuss benefits and challenges in this learner-centered environment, and review student feedback and the impact of this approach on student learning. (Received September 16, 2014)

1106-G5-1752 **Yun Lu*** (lu@kutztown.edu), Mathematics Department, Kutztown University of PA, Kutztown, PA 19530. *Applying the Inquiry-Based Learning Elements in Teaching Calculus II class.*

During this talk, I want to share my experience of applying the inquiry-based elements to enhance students' learning in my calculus class. I will talk about my motivation, problems encountered, success received, as well as students' feedback. (Received September 15, 2014)

1106-G5-1778 **Li-An Daniel Wang*** (daniel.wang@trincoll.edu), 300 Summit Street, Hartford, CT 06106. *Modified Moore Method in Introduction to Proofs.* Preliminary report.

Even for students having taken a course introducing them to proofs, real analysis can still be very challenging. We designed a course that exposes students to more proofs and basic analysis ideas, using a modified Moore Method. We discuss how the course was conceived and received by the students. (Received September 15, 2014)

1106-G5-1818 **Hansun To*** (hto1@worcester.edu), 486 Chandler Street, Math Department, Worcester, MA 01602. *IBL in a Liberal Arts Mathematics Course.*

Each semester Worcester State University offers several sections of Survey of Math, MA105. This is a course taken by many undergraduates not majoring in the mathematical or life sciences, to satisfy a quantitative reasoning course of Liberal Arts and Science Curriculum requirements for graduation.

It is intended to support students' liberal arts and social science interests, by investigating applications of mathematics in contexts which are relevant to individuals without strong interests in the mathematics.

I have adapted the inquiry based lecture/learning to this course since 2012. I will share the improvement of assessment, compare with other non-IBL sections and pros and cons of using this particular technique at the introductory level of studying. (Received September 15, 2014)

1106-G5-1884 **Brian Fisher***, brian.fisher@lcu.edu, and **Jason Samuels**, **Aaron Wangberg** and **Eric Weber**. *Raising Calculus to the Surface: Using Physical Surfaces to Facilitate Inquiry-Based Learning in Multivariable Calculus.* Preliminary report.

One significant challenge in bringing inquiry-based learning materials to multivariable calculus is creating opportunities for students to engage meaningfully with functions of more than one variable. To meet this challenge, we have developed a set of physical surfaces, measurement tools, and corresponding activities that allow students to discover many of the key concepts from multivariable calculus. In this talk we will give an overview of this project, demonstrate how these materials can be used to develop methods for optimizing along a constraint, and share results from students and instructors implementing these materials in their classroom. (This research is funded in part by the National Science Foundation as part of the Raising Calculus to the Surface project, DUE #1246094) (Received September 15, 2014)

1106-G5-1971 **Therese Shelton*** (shelton@southwestern.edu). *POGIL Flu for Calculus: Influenza Data to Help Students Investigate Antiderivatives, Accumulations, and FTC.*

Student responses about accumulation functions and The Fundamental Theorem of Calculus improved after completing an IBL-based activity using flu data. The activity was designed according to guidelines from an MAA PREP POGIL Workshop. (Received September 15, 2014)

1106-G5-1982 **Joseph W. Eyles*** (jeyles@gordonstate.edu). *IBL College Algebra.* Preliminary report.

For those of us who employ inquiry in our learning, it seems natural to employ IBL in teaching. However, college algebra students may be new to IBL and have difficulties adapting to this approach to learning. In acknowledgement of the importance of college algebra as the final course in mathematics for many students and the difficulties some of them have with the IBL method, the presenter identified some possible changes to improve his delivery of an IBL college algebra course. This report discusses effectiveness of changes that began in 2011 with support from The Educational Advancement Foundation. (Received September 15, 2014)

1106-G5-2059 **Carl Toews*** (ctoews@pugetsound.edu), 318 N Yakima Ave, Tacoma, WA 98403. *Computational inquiry in elementary statistics.*

The profusion of data in almost every aspect of applied science has made statistics an important course in the undergraduate curriculum. Unfortunately, many undergraduates who take elementary statistics have an uneasy relation with mathematics, and strongly theory-based approach can lead to frustration and other negative reactions. On the other hand, introductory statistics courses often have a tightly prescribed set of topics, coverage of which can be hard to reconcile with a more open ended, exploratory approach.

The purpose of this talk is to report on my experience using computational guided inquiry in the R programming language as a means of bringing an inquiry based learning approach into the elementary statistics classroom. The computational work is structured just like the sequenced activities of conventional inquiry based learning, but it is implemented on the student's own laptops, and is augmented by group work, file sharing, and physical lab notebooks. In additional to building fluency with statistical ideas, this approach also cultivates computational literacy, and ultimately empowers students to view their laptops as exploratory tools. (Received September 15, 2014)

1106-G5-2071 **Chris L Rasmussen*** (chris.rasmussen@sdsu.edu), Department of Mathematics and Statistics, 5500 Campanile Drive, San Diego, CA 92182-7720. *Creating and Sustaining Productive Whole Class Discussions.*

In order to create a learning environment that encourages students to ask good questions, an instructor needs to initiate, sustain, and facilitate substantive and rigorous whole class discussions. However, creating such inquiry-oriented classrooms is no easy task. In this presentation I draw on insights from research projects in linear algebra and differential equations to highlight five goals for student participation and corresponding instructor discourse moves that can be used to achieve these goals. The five goals for student participation are: (1) helping individual students share their own thoughts, (2) helping students orient to and listen carefully to one another, (3) helping students deepen their reasoning, (4) helping students engage with others' reasoning, and (5) building on and extending students' ideas. For each of these goals, prototypical instructor prompts, questions, and requests will be tendered provided using examples from research projects in linear algebra and differential equations. These prototypical instructor moves constitute a set of routines that others can adapt in their efforts to create inquiry-oriented classrooms, whether the content be linear algebra or abstract algebra or real analysis. (Received September 15, 2014)

1106-G5-2253 **Kevin Hartshorn*** (hartshornk@moravian.edu), 1200 Main St., Bethlehem, PA 18018. *Writing Across the Curriculum and IBL.* Preliminary report.

Writing across the curriculum (WAC) programs are institution-wide initiatives designed to encourage students to use writing not just as a means of communication, but as part of the learning process itself. Through journals, writing workshops, reading response essays, and other targeted writing assignments, students are called to engage in the learning process. In this presentation, I will share ways in which my work with our first year seminar and WAC has translated to stronger inquiry-based lessons in mathematics. While my talk will focus on activities in first semester calculus and basic liberal-arts math courses, I have found that many of these techniques have fared quite well in my junior/senior algebra and geometry courses. (Received September 16, 2014)

1106-G5-2281 **Amy Ksir*** (ksir@usna.edu), **Christine von Renesse** (cvonrenesse@westfield.ma.edu) and **Margaret C. Nikolov** (nikolov@usna.edu). *Inquiry-Based Calculus III.* Preliminary report.

The first author has taught Calculus III (multivariable calculus) nine times in the past 11 years. Two years ago she "took the plunge" and switched from an interactive lecture / homework-from-the-textbook format to an inquiry-based format centering on student presentations. We will present a comparison of various student learning outcomes from "before" and "after," analyzed with the help of the third author. We will describe the problem set developed by the first and second authors that replaces the course textbook; it has also been successfully used by the second author in an IBL class centered on group work. (Received September 16, 2014)

1106-G5-2417 **Theron J Hitchman*** (theron.hitchman@uni.edu), Department of Mathematics 0506, University of Northern Iowa, Cedar Falls, IA 50614. *IBL Linear Algebra with a mixed audience and Sage.*

We present a framing of an IBL classroom aimed at a mixed audience of students from mathematics and from client departments that has a significant technology component. The main adaptations involve finding a reasonable standard of argument for a course that is not based on formal proof, and developing a way to integrate the use of the mathematical computing software Sage as a tool for mathematical investigation. (Received September 16, 2014)

1106-G5-2429 **Candice M Quinn*** (c.m.quinn45@csuohio.edu), 2121 Euclid Ave, Mathematics Department, RT 1547, Cleveland, OH 44115. *The Developement and Implementation of Inquiry-Based Learning Projects in Precalculus and Calculus.*

This paper discusses the evolution of the inquiry – based learning projects used in our courses throughout the 2013 – 2014 school year: Precalculus I (Building a Bridge), Precalculus II (Exploring Trigonometry through Sound) and Calculus I (Formula 1 Racing Strategy). We will include the description, technology and implementation methods used for each project along with student feedback. (Received September 16, 2014)

1106-G5-2446 **John C Mayer*** (jcmayer@uab.edu). *Inquiry-Based Learning on the Way to Calculus.* Preliminary report.

Studies that we did at UAB in 2010, 2011, and 2013 point, in different ways, to the potential for IBL class meetings in pre-calculus courses to improve the chances of students to perform satisfactorily in Calculus I. The studies in 2010-11 were quasi-experimental studies of incorporating IBL/Group Learning sessions in Basic Algebra (a remedial course), reported at the Conferences on Research in Undergraduate Mathematics Education the subsequent years. The 2010-11 studies led to a change in how we teach Basic Algebra from 2012 onward. The 2013 study was a statistical study of success of students in Calculus I in the period 2006-2012 based upon the first mathematics course taken at UAB. The 2013 study pin-pointed where we could get the most "bang for the buck" in subsequent student success in Calculus, if we made an appropriate change in instruction. Of course, the study does not imply what type of change is appropriate. I will outline a two-pronged approach (one quasi-experimental, one statistical) to help resolve this issue. (Received September 16, 2014)

1106-G5-2468 **William G. Hager*** (whager@tlu.edu), Math/CS Dept., Texas Lutheran University, 1000 W. Court St., Seguin, TX 78155. *Teaching an Inquiry-Based Elementary Linear Algebra Course at a Small Liberal Arts University.*

The Elementary Linear Algebra course at Texas Lutheran University is a hybrid inquiry-based/lecture course usually offered once a year. The small class size and variety of majors in the classroom presents challenges for inquiry-based teaching.

In this talk, we will detail some of these challenges and briefly discuss the set of notes used for the course. We will also look at data from final exams, student surveys, and student comments. (Received September 16, 2014)

1106-G5-2474 **Kathleen Grace Kennedy*** (kennedyk2@wit.edu), Wentworth Institute of Technology, 550 Huntington Avenue, Boston, MA 02115, **Naomi Ridge** (ridgen@wit.edu), Wentworth Institute of Technology, 550 Huntington Avenue, Boston, MA 02115, **Rachel Maitra** (maitrar@wit.edu), Wentworth Institute of Technology, 550 Huntington Avenue, Boston, MA, **James O'Brien** (obrienj10@wit.edu), Wentworth Institute of Technology, 550 Huntington Avenue, Boston, MA 02115, and **Franz Rueckert** (rueckertf@wit.edu), Wentworth Institute of Technology, 550 Huntington Avenue, Boston, MA 02115. *Teaching Physics-Calculus with Applications to Engineering.* Preliminary report.

At Wentworth Institute of Technology, several engineering majors take physics I and calculus I at the same time. In the past, these courses being out of synch have caused difficulties for biomedical and mechanical engineering students taking them as co-requisites. In our presentation, we will report on the materials we developed and preliminary results on the impact of our course.

Our team developed curriculum for a synergetic inquiry-based course integrating physics and calculus, such that each subject reinforces the other. Students obtain a visual or physical "picture" to support the comprehension of calculus; likewise, physics will be presented not merely as an application of calculus but as its raison d'etre. In summary, we are teaching calculus through the lens of physics using context-driven and inquiry-based course material.

Our work was funded by a grant from the Academy of Inquiry Based Learning and the Education Advancement Foundation. (Received September 16, 2014)

1106-G5-2506 **Girija S Nair-Hart*** (nairhaga@uc.edu), 3585, Applewood drive, Amelia, OH 45102. *Reasons behind rules – aligning the 'unreachable' asymptotes.* Preliminary report.

During my research on student conceptions of different calculus and pre-calculus concepts, calculus students accidentally discovered that asymptotes are geometric constructs that both functions and non-functions can hold. These students came from diverse academic standings in mathematics while they held the commonality of choosing their careers in the engineering track. The students were marveled by their own discovery, they took pride that they explored the concepts by actively listening to their peers, pointing out the discrepancies in each others views, looking at different examples and negotiating meanings that aligned better with the mathematical truth accepted by the mathematics community. In the end, they also cleared their long-standing confusion on what fits and does not fit with characteristics of asymptotes. What I learned from this experience as an instructor was that well-crafted collaborative assignments could help build confidence and enthusiasm in mathematics students. During this presentation I will discuss the details of this episode to demonstrate what collective, discovery learning efforts could accomplish. (Received September 16, 2014)

1106-G5-2578 **Oscar Chavez*** (oscar.chavez@utsa.edu), Department of Mathematics, One UTSA Circle, San Antonio, TX 78249. *Inquiry-Based Learning in Honors Calculus I.* Preliminary report.

First year Calculus courses are usually taught with the purpose of teaching students a set of specific methods and procedures of calculus related to limits and derivatives, and their applications to "real life" problems. While this may be an efficient way to convey abundant information to students in a limited time, it frequently results in students' misunderstandings of basic concepts of calculus and a limited ability to prove and present arguments in mathematics. In this paper we discuss the implementation of an inquiry-based Calculus I course for honors students. Through the examination of assessment data, survey data, and anecdotal evidence we show that the course fostered positive attitudes about mathematics and encouraged multiple approaches to solving problems. We show that this type of course has some clear advantages over lecture-based courses. We also discuss the challenges of implementing such a course into a class where there is an expectation of covering a considerable amount of material. (Received September 16, 2014)

1106-G5-2644 **McKenzie R. Lamb*** (lambm@ripon.edu). *Using IBL to Bridge the Gap Between Math for Liberal Arts and Intro to Proofs.* Preliminary report.

Teaching a course that is supposed to be simultaneously an introduction to proofs for math majors and a math for liberal arts course for non-majors is a daunting undertaking. The primary challenge is in keeping the non-majors on board while keeping the majors from getting bored. I will describe using a hybrid IBL structure to meet this challenge in a course at a small, liberal arts college. I will focus on the nuts and bolts of implementation: grading, presentations, etc. (Received September 16, 2014)

1106-G5-2714 **Rachel Schwell*** (schwellrac@ccsu.edu). *Inquiry-Based Activities in a Precalculus with Trigonometry Course.*

I have been teaching upper-level courses via a modified Moore Method for several years now, but did not feel this approach would be as suitable for our freshman-level Precalculus with Trigonometry course. However, the underlying principles of the Moore Method have found their way into my pedagogy in this setting through in-class activities, group work, and student sharing of solutions. I will share some of these activities and describe the logistics of running the course in this fashion, and will close with some outcomes, both measured and anecdotal. (Received September 16, 2014)

1106-G5-2846 **Paul E Seeburger*** (pseeburger@monroecc.edu), 1000 E. Henrietta Rd., Rochester, NY 14623. *Exploring Velocity and Acceleration Vectors Visually.* Preliminary report.

In multivariable calculus, we ask students to calculate vector-valued functions for velocity and acceleration, given a position function. Students often find it easy to visualize the velocity vector being tangent to the space curve, but they rarely have a clear picture of the acceleration vector and its relationship to the motion and to the corresponding velocity vector. Using a freely available online multivariable calculus applet called CalcPlot3D, students can complete a guided exploration of velocity and acceleration. As part of this guided activity, students complete a pre-test, answer exploration questions, and then complete a post-test. After students have completed this activity, there is often a lively class discussion about the interaction between the acceleration and velocity vectors they observed in the dynamic examples from the exploration. Through this discussion most misunderstandings are cleared up, and students become more confident in what they learned from the exploration. In addition to demonstrating this online exploration, analysis of the pre- and post-test results and student comments on their own learning will be shared. CalcPlot3D is part of an NSF-funded grant project (DUE- CCLI #0736968). See http://web.monroecc.edu/calcNSF/. (Received September 16, 2014)

1106-G5-2851 **Annie Y Han*** (yhan@bmcc.cuny.edu), 199 Chambers St., New York, NY 10007, **Michael George** (mgeorge@bmcc.cuny.edu), 199 Chambers St., New York, NY 10007, and **Yevgeniy Milman** (ymilman@bmcc.cuny.edu), 199 Chambers St., New York, NY 10007. *An inquiry-based learning in Developmental Mathematics Course.*

Mathematics teaching and learning can be seen, through a cultural lens, as an exchange of information. The richness of that exchange, and in turn of the culture of the mathematics classroom, depends upon the way in which inquiry is employed. This presentation describes the implementation of a rigorously inquiry-based approach to mathematics education in the context of a developmental-level mathematics course. over the first two years of this implementation, students enrolled in inquiry-based learning developmental mathematics sections were significantly more likely to pass the course than students taking the traditional developmental course.

Furthermore, of the students who went on to take credit-bearing mathematics, the students from the inquiry-based sections were more likely to pass that course than the students from the traditional developmental course. (Received September 16, 2014)

Mathematics and the Arts

1106-H1-69 **Annalisa Crannell*** (annalisa.crannell@fandm.edu), PA, and **Marc Frantz** and **Fumiko Futamura**. *Desargues's Theorem and drawing shadows: a discovery-based approach.*

Projective Geometry applied to Perspective Art is an inquiry-based course designed for sophomore- and junior-level mathematics majors. This talk highlights two of the modules we have developed for this course. The first module has students devise, explore, and compare solutions to an art problem: how to draw the shadow of the letter 'A' using ruler, pencil, and eraser. From there, students investigate the geometry of projected triangles via *Geogebra* to discover Desargues's Theorem. The second module uses a modified Moore method approach to lead students toward a rigorous proof of Desargues's theorem. (Received June 26, 2014)

1106-H1-74 **Fumiko Futamura*** (futamurf@southwestern.edu), TX, and **Annalisa Crannell** and **Marc Frantz**. *Harmonic ratios: music and art in an inquiry-based Geometry course.*

Projective Geometry applied to Perspective Art is an inquiry-based course designed for sophomore- and junior-level mathematics majors. This talk highlights two of the modules we have developed for this course. The first module has students discover and make conjectures concerning a projective invariant called the harmonic ratio and more generally the cross ratio through exploring rectangles and rows of rectangles in perspective. In the second module, students experiment with stringed instruments to understand harmonics in music, the harmonic sequence and their connections to the harmonic ratio. (Received June 28, 2014)

1106-H1-332 **Jonathan P Keiter*** (jkeiter@esu.edu). *Anamorphic Art and Mathematics.* Preliminary report.

I will describe my work on an art instillation at my university. A collaboration between the Math and Art departments, we created an anamorphic mural of Albert Einstein. Using geometry and linear algebra, the mural displays the original image of Einstein when seen from only one viewpoint. The image with original dimensions of 8x5 was transformed into an 8x23 mural. A brief history of anamorphic art work and the underlying mathematics will be presented. In the spring, I used math club meetings to get students involved. I will discuss ways I incorporated anamorphic art and other forms of art into a modern geometry course this fall. (Received August 22, 2014)

1106-H1-425 **Daniel M Look*** (dlook@stlawu.edu), SLU Department of Mathematics, St Lawrence University, 23 Romoda Drive, Canton, NY 13617. *Addressing the Contested Authorship of CM Eddy's "The Loved Dead" using Stylometry.* Preliminary report.

The authorship of the 1924 short story "The Loved Dead" has been contested by family members of Clifford Martin Eddy, Jr. and scholars of Howard Phillips Lovecraft. There is argument between the two authors' supporters that the work is entirely that of the respective author, but there is no direct evidence toward either claim. The authors of this paper attempt to use stylometric methods in order to lend evidence toward a claim of authorship for "The Loved Dead" using lexical richness measurements, function word tests, and Burrows's Delta. We find that "The Loved Dead" and two other Eddy stories that are known Lovecraft revisions cannot be as easily distinguished as tales known to be solely written by each author, which may imply that neither Eddy nor Lovecraft is the sole author. (Received August 27, 2014)

1106-H1-495 **Laura Taalman*** (laurataalman@gmaill.com). *3D-printed research: Combining mathematics and art to introduce students to knot theory.*

In this talk we will discuss a semester-long mathematics course in which students created artistic 3D-printed models of various knot conformations as a way to explore knot-theoretical properties and current knot theory research. The artistic side of this project enabled strong collaboration between both early math students and upper-level math students, as well as between students with and without prior design experience. The project encouraged an exploration of shape and form both functionally and in terms of known knot classifications. The end result of this course was a set of fifteen 3D-printed knot models, each of which illustrates a special property or form of knots. (Received August 30, 2014)

1106-H1-673 **Marc Frantz*** (mfrantz@indiana.edu), Department of Mathematics, Indiana University, Bloomington, IN 47405, and **Fumiko Futamura** and **Annalisa Crannell**. *Hyperbola: Under Construction!*

We examine a perspective illusion in a picture of a building under construction, and find that it illustrates various mathematical topics, including conic sections and graphs of rational functions. In the setting of projective geometry, the illusion motivates the discussion of perspectivities, projectivities, and Steiner's definition of a conic. The picture also suggests the design of a classic hyperbola-drawing linkage attributed to Descartes, which we demonstrate with Geometer's Sketchpad. (Received September 04, 2014)

1106-H1-808 **Rosanna Iembo*** (rosannaiembo@libero.it), via Federico Cozzolino, 18, Scafati, Salerno 84018, and **Irene Iaccarino** (irene.iaccarino@hotmail.it), via Interna Marina 19, Crotone, 88900. *6th or 5th century before Christ: the start up of globalization, the beginning of a magic.*

When Pythagoras died, his followers were in despair. This is the end: they thought. But so it was not. Theano, the wife of Pythagoras, mathematician and the first great scientist of mankind, was his husband's spiritual heir and she saw to it that their school, founded in Crotone, in southern Italy, did not finish. With their children she spread the Pythagorean thought and wisdom in the ancient west. And the "globalization" of knowledge began. She kept an important training for their followers to constitute new Pythagorean communities in other cities of the ancient world around the Mediterranean: Philolaus founded a new School in Thebes at the end of the fifth century. But he returned later to Italy and refounded a school at Taras. At Taras lived Archytas, a friend of Plato. Plato observed Pythagorean societies in Italy when he went there to visit his friend. And Timaeus, a Pythagorean man, became the protagonist of his dialogue. Offshoots of the Pythagorean academy continued for some 300 years after its founder's death. Pythagoras and Theano heralded and inspired all those philosophic-scientific systems: Socratic, Stoic, Neoplatonic. The philosophy and the wisdom of Pythagoras and Theano continue to inspire the thought of scientists around the world. Up till now. (Received September 07, 2014)

1106-H1-1134 **Douglas Dunham*** (ddunham@d.umn.edu), Department of Computer Science, University of Minnesota, Duluth, Duluth, MN 55812-3036, and **John Shier** (johnpf99@frontiernet.net), 6935 133rd Court, Apple Valley, MN 55124. *An Algorithm for Creating Artistic Random Fractal Patterns.* Preliminary report.

We describe an algorithm that creates aesthetic patterns by randomly filling a bounded region of the plane with progressively smaller copies of a motif. For circles or ellipses our process produces fractal patterns which are reminiscent of various sized pebbles on a stream bed.

The algorithm starts by placing the largest copy of the motif at some random location in the region. After placing i motifs, the algoritm selects a random trial location within the region at which to place the next motif. If the new motif does not overlap any previously placed motif (whose locations are stored in an array), then this is a successful placement and i is incremented; otherwise another trial location is selected, and this sub-process continues until there is a successful placement. In order to guarantee that copies of a motif fill a region in the limit, it has been found that the area A_i of the i-th motif must be proportional to $(N+i)^{-c}$, where $c>1$ and $N>0$ are parameters.

This algorithm has proved to be quite robust in that it can successfully fill regions of various shapes, incuding non-simply-connected regions. Also the motifs need not be connected or simply-connected. We will show a number of sample patterns that explore these possibilities. (Received September 11, 2014)

1106-H1-1162 **Vi Hart** (vi@vihart.com) and **Henry Segerman*** (segerman@math.okstate.edu). *The quaternion group as a symmetry group.*

We discuss the question of which groups have appeared as the symmetry groups of physical objects. To our knowledge, the quaternion group (a beautiful group with eight elements) has not appeared in this fashion. We describe the quaternion group, both formally and intuitively, and give our strategy for representing the quaternion group as the symmetry group of a physical sculpture. (Received September 11, 2014)

1106-H1-1255 **Douglas G Burkholder*** (burkholderd@lr.edu), Lenoir-Rhyne University, 625 7th Ave NE, Hickory, NC 28601. *Visualizing Affine Regular, Area-Preserving Decompositions of Irregular 3D Pentagons and Nonagons.*

We demonstrate a simple, elegant, and visual method for decomposing irregular pentagons into a pair of affine images of the two distinct types of regular pentagons. Moreover, the sum of the area of the two affine images equals the area of the original irregular pentagon. Similarly, we decompose irregular nonagons into a quadruple of affine images of the three distinct types of regular nonagons and one triangle. One can use these decompositions to design visually interesting sculptures reflecting these geometric relationships. (Received September 11, 2014)

1106-H1-1256 **Karl H Schaffer*** (karl_schaffer@yahoo.com), 325 Lucinda St., Scotts Valley, CA 95066. *Dancing Deformations.*

The performance art of dance employs symmetry in a variety of ways. Often choreographers blur the lines between symmetries or seamlessly morph from one symmetry type to another. This may be seen to be similar to parquet deformations, visual images by artists such as M.C. Escher, in which one tiling is deformed seamlessly into another. We look at ways linear or frieze symmetries, common in folk dance and other forms, and planar or wallpaper symmetries used in a variety of dance forms may be switched from one to another in time, with particular attention to the Klein four group. The sequences through danced wallpaper symmetries might make for entertaining mathematical flash mob dances. (Received September 11, 2014)

1106-H1-1655 **Robert M Spann***, 3001 Veazey Terr., NW, Apt 802, Washington, DC 20008. *Creating Rhythm and Repetition In Algorithmic Images Using Non-Dihedral Elements of S_4.*

Rotations and reflections of a square are often used to create highly structured algorithmic images. These group operations generate the Dihedral group, D_8. This group is a subgroup of the much larger group, S_4, the group of all permutations of four items. I use the elements of S_4 that are not members of D_8 along with reflections to generate images. The starting point is an element; a square divided into four squares each a different color. I fill the image plane by translating this element horizontally and vertically plus apply a non-dihedral element of S_4 to permute the four squares of the element. This process produces a grid in which each square is one of four colors. I then develop an analogy between group operations and the conventions of meter and rhyming pattern found in poetry. Two lines of elements have the same 'meter' if the horizontal movement from one element to the next involves the applying the same element of S_4 . Two lines of elements 'rhyme' if one is a vertical reflection of the other. The result of this process is images that initially appear random, but on on further study, have a rich underlying structure. (Received September 14, 2014)

1106-H1-1669 **Reza Sarhangi*** (rsarhangi@towson.edu), Department of Mathematics, Towson University, 8000 York Road, Towson, MD 21252. *Methods for Creating Mosaic Designs.*

There are a few methods for constructing some interlocking star patterns that are presented:

(a) The Radial Grid Method: A method that was used in medieval times, which is supported by the 13th century treatise, Interlocks of Similar or Complementary Figures.

(b) The Polygons in Contact Method: In some literature, another technique, "polygons in contact" (PIC), has been introduced and discussed in a few recent articles. This is another system for which there exists evidence of historical use by designers.

(c) A Method based on the n/k Star Polygons: One may construct the same pattern using a technique based on the use of a 10/3 star polygon and the extensions of some of its sides.

(d) Modularity Method: Modularity offers another interesting approach for creating the layout of a mosaic pattern (that is, for conceptualizing but not necessarily making the individual actual tiles that compose the final tiling). This method has been suggested as the means used in ancient cultures, such as those during the Paleolithic period. (Received September 14, 2014)

1106-H1-1703 **David Peifer*** (dpeifer@unca.edu). *Mathematics in the works of Dorothea Rockburne.*

Dorothea Rockburne is one of America's most important contemporary artists. A few months ago, she helped to install her work, Folding Sky, Homage to Colin Powell, at the United States Embassy in Kingston, Jamaica. This forty foot high mural depicts the night sky the day that Colin Powell was born. Her recent exhibition, Drawing Which Makes Itself, at the MoMA in NY City marked her influence on modern art for over half a century. Throughout Ms. Rockburne's career, her work has been influenced by her love for mathematics. By an extraordinary set of events, as an undergraduate student at Black Mountain College, Ms. Rockburne studied with the world class topologist Max Dehn in the last years of his life. This talk will investigate how mathematics has played a role in Dorothea Rockburne's life and art. (Received September 15, 2014)

1106-H1-1750 **Heidi Burgiel*** (hburgiel@bridgew.edu), Mathematics Department, Bridgewater State University, Bridgewater, MA 02325. *Motivating Math with Unit Origami.*

Learn to fold a modified Sonobe module and assemble a cube! In addition to the cube – which is a stellated tetrahedron – this module can be used to stellate octahedra, icosahedra and many other deltahedra.

Construction of these beautiful objects motivates many mathematical questions. What size paper would you need to create a one inch cube? How is the cube related to its inscribed tetrahedron? What is the angle between the original face and the stellating face? What else can we make from this unit? How can we describe or enumerate the possibilities?

From crafting holiday ornaments to engaging students, unit origami is intriguing and rewarding. (Received September 15, 2014)

1106-H1-1796 **Randall E Cone*** (conere@vmi.edu), 410 Mallory Hall, Virginia Military Institute, Letcher Avenue, Lexington, VA 24450. *Perchance to Dream: The Mathematics of Hamlet.*

In this session, we explore mathematical visualizations and analyses of Shakespeare's most famous work. (Received September 15, 2014)

1106-H1-1816 **Craig M. Johnson*** (johnsonc@marywood.edu), Marywood University, 2300 Adams Ave, Scranton, PA 18509. *Using Audio Segments to Present Math-Music Connections.*

Technology can be used in many ways to demonstrate the presence of mathematics in many other disciplines. In this talk I show effective ways to imbed audio segments into powerpoint slides that show the connections between mathematics and music. Simultaneously using more than one sense to weave together information helps to re-enforce certain concepts. (Received September 15, 2014)

1106-H1-1826 **Vincent J. Matsko*** (vince.matsko@gmail.com). *Color, Texture, and Geometry.*

What distinguishes computer-generated art from other art genres? The ease of changing color palettes allows for experimentation not possible with conventional pigments. Randomness of color and size of thousands of individual geometrical objects produces textures which would be difficult to produce otherwise. Finally, the use of vector graphics allows for explorations with scale and size not possible with a physical canvas. Examples of computer-generated art using these techniques will be presented and discussed. (Received September 15, 2014)

1106-H1-1850 **Srividhya Balaji*** (bsrividhya90@gmail.com), Department of Mathematics, Pittsburg State University, 1701 S Broadway St, Pittsburg, KS 66762. *Connections between Indian Classical Music and Mathematics.*

Mathematics, as we all know, is the elixir of life. It is the language of all the arts and sciences. When it comes to music, the role of mathematics is clearly evident in terms of rhythm, melodic patterns, or the extempore improvisations.

Music and mathematics are intricately related, but there is not an equation that will model all works of music. However, there are certain mathematical structures inherent in all works of music. Indian classical music utilizes mathematical concepts like set theory, functions, coordinate transformations, permutations and combinations, limit points, etc. in every piece of its music. The language of mathematics helps us comprehend this underlying structure. This presentation will mainly focus on the different mathematical concepts involved in the classical music of India. (Received September 15, 2014)

1106-H1-1893 **Margaret Kepner*** (renpek1010@gmail.com). *Visualizing Partitions of Integers.* Preliminary report.

Partitioning provides a useful tool for describing the properties of integers. Every integer can be decomposed into a sum of terms (an additive partition) and also into a product of factors (a multiplicative partition, or factorization). Partitions of integers are studied in their own right; furthermore, the topic has applications in number theory and combinatorics. Various diagrams have been developed to help visualize and classify partitions. In this presentation, I will review several of these visual tools, and also explore some alternative presentations. Finally, I will show examples of how I have employed visualizations of partitions in my artistic work. (Received September 15, 2014)

1106-H1-1979 **Elizabeth Whiteley*** (contact@elizabethwhiteley.com). *Creative Uses of Basic Geometry to Construct Elegant Pattern Designs.*

Pattern design relies on symmetry and repetition. If the symmetry and repetition is grasped too easily by the viewer, a pattern can become uninteresting. I show how to use a few basic geometric operations to create half drop surface design patterns which appear both fresh and complex to the viewer. This talk presents ways to transform 2-D design elements within generators for p1 translations. Examples will demonstrate this new approach to constructing elegant patterns from lattice plans based on square, parallelogram, rhombus, and quadrilateral shapes. (Received September 15, 2014)

1106-H1-2130 **David A. Reimann*** (dreimann@albion.edu), Mathematics and Computer Science Department, 611 E. Porter St., Albion, MI 49224. *Halftoning images using solid convex and nonconvex dodecagons on a hexagonal tessellation.*

Halftoning is an image rendering method that conventionally uses solid circles of varying size and spacing to produce a given image. A halftoning method is presented where hexagons on a hexagonal tessellation are used instead of circular dots. Rather than varying the diameter of the hexagonal dots, the edge midpoints are deflected outward or inward to increase or decrease the effective dot size respectively. When deflected inward, the hexagons become relatively smaller star shaped nonconvex dodecagons and the effective dot size is decreased. When deflected outward, the hexagons become relatively larger convex dodecagons and the effective dot size is increased; in theory star shapes could be formed, however the star points would overlap adjacent stars. Example of this method will be presented, including printed and laser cut images. The interplay among the stars, the hexagonal lattice, and the underlying base image gives an image rendered with this technique visual interest. (Received September 15, 2014)

1106-H1-2131 **Lee Stemkoski*** (stemkoski@adelphi.edu), Adelphi University, 1 South Ave., Garden City, NY 11530. *Rendering Photorealistic Knots: Theory and Practice.*

We present a series of photorealistic 3D renderings of ropes based on polynomial and trigonometric parameterizations of topological knots, and explain how these images can be created using Blender, a free and open-source modeling and rendering program. We also discuss how the mathematics underlying the techniques used in this process, including extruding a circle along a curve, UV mapping, and displacement mapping, can be presented as an enrichment lesson for a multivariable calculus course. (Received September 15, 2014)

1106-H1-2317 **James Morrow*** (jmorrow@mtholyoke.edu). *Studio Art Assignments in a Liberal Arts Geometry Course.*

I give examples of studio art assignments and a rationale for including them in mathematics courses in terms of:

1. Illustrating the nature of mathematical ways of knowing,
2. Encouraging hands-on experimentation as one starts to learn new mathematical concepts, and
3. Developing life-long skills, such as becoming more observant, reflective, and active. (Received September 16, 2014)

1106-H1-2322 **R. Daniel Hurwitz*** (dhurwitz@skidmore.edu), Department of Mathematics and Computer Scienc, Skidmore College, Saratoga Springs, NY 12866. *Van Kampen Tessellations.*

The geometry of the different tessellations of the plane and the algebra of their symmetry groups make an interesting confluence of mathematics and art. Usually, one starts with tilings and then studies their mathematical structures. I would like to approach from the opposite direction. Let us begin with some groups and examine some tilings they generate. In particular, we begin with a particular construction based on a presentation of a group called a Van Kampen (or R-) diagram which often come up in geometric group theory. These diagrams can be used as a tool to construct isogonal tessellations of the plane. Can we find any attractive ones? (Received September 16, 2014)

1106-H1-2332 **Sarah Stengle*** (stenglesarah@centurylink.net) and **Rebekah Dupont**. *Aesthetics and motivating principles: comparing mathematical art to contemporary art.* Preliminary report.

Using images from the history of mathematical art and recent contemporary art, this talk will address aesthetic questions, as well as the notion of the anti-aesthetic. Non-practitioners often have a limited view of both fields. For example, non-mathematicians may think mathematicians are not creative because, in their experience, there is one true pre-determined solution. Similarly, non-artists often think that the goal of an artist to simply to create a universally agreed-upon beauty. The human practice of both these disciplines is often process-oriented, wherein the product is a string of related results continually refined through the process of working on them. The notion of absolute solutions in either discipline can be philosophically problematic. The talk will touch on the writings of Bertrand Russell, Alfred North Whitehead, and Elaine Scarry, and will focus primarily on comparing mathematical art to contemporary art. (Received September 16, 2014)

1106-H1-2378 **John H Wilson*** (john.wilson@centre.edu), 600 West Walnut Street, Danville, KY 40422. *A Glass Cane Project in Calculus II.*

Rods of glass called canes are used by glass artists to add colorful patterns to their work. In this talk I will describe the results from a Calculus II group project in which students posed and answered questions inspired by designing glass canes. I will draw connections between geometry, calculus, parametric equations and space curves in addition to describing the role played by a class visit to the glass studio where the canes were being made. (Received September 16, 2014)

1106-H1-2522 **Van Herd*** (herd@austin.utexas.edu), College of Undergraduate Studies, University of Texas at Austin, Austin, TX 78712. *M^2ART(Mathematics, Museums, and ART): A Renewable Pedagogical Resource.*

In this session, the author will present his experiences, lessons learned, and data gathered from being able to use successfully the rich resources of large university museum culture in the teaching of a wide range of undergraduate mathematics courses from developmental to honours, as well as data from courses designated or "flagged" as quantitative literacy courses at the University of Texas at Austin.

While these examples are based upon the Harry Ransom Center for the Humanities and the Blanton Museum of Art at Texas, they present mathematics-through-art pedagogical opportunities that are easily replicable in a variety of university and college settings. (Received September 16, 2014)

1106-H1-2550 **Andrew J Miller*** (andrew.miller@belmont.edu). *Linking Mathematics and the Arts through a Poster Assignment.*

As part of Belmont University's general education curriculum, all first-year students take a pair of "linked" courses. I recently linked an introductory mathematics course with an introduction to art course. In addition to briefly looking at the list of topics we explored in the math course, I will share the details of a common assignment we developed that asked the students to use artistic skills to present a mathematical topic. (Received September 16, 2014)

1106-H1-2679 **Ellie Baker***, ellie.baker@post.harvard.edu, and **Susan Goldstine**. *Make Your Own Torus Knot – Crafty Constructions in Bead Crochet and Beyond.*

This talk describes two thought experiments that help elucidate the elegant structure of torus knots and suggest design and construction techniques applicable to bead crochet and other materials.

In one thought experiment, we use a diagonal line spanning a P by Q patchwork of infinitely thin, transparent, flat tori and then join all identifying points to construct the desired (P, Q) knot. In a second thought experiment, we start with a single flat torus with Q evenly spaced vertical lines, roll it into a cylinder, apply a P/Q twist to one end, and join the two ends to form the desired (P,Q) knot. We show how these ideas can be applied to practical torus knot constructions in bead crochet, clay, and cookie dough, with potential for fun, possibly wearable or edible, hands-on exploration and learning. The thought experiments and bead crochet constructions are described in our new book, Crafting Conundrums: Puzzles and Patterns for the Bead Crochet Artist. (Received September 16, 2014)

1106-H1-2746 **Dina Buric***, 516 High Street, Bellingham, WA 98225, and **Teresa Downard**. *Folding, imagining, and constructing a math and art class.* Preliminary report.

As mathematics teachers, our goal is not just to teach methods, but to encourage creative and innovative mathematical thinking. There are a myriad of topics at the intersection of mathematics and art that offer challenging problems to play with. Paper, fiber, clay and pencil can be used to fold, weave, sculpt and draw, giving mathematical concepts a whole new perspective. By creating inquiry-based lesson plans we hope to cultivate an environment where original ideas are not just encouraged, but expected. In this session we will present our experience incorporating these types of problems in the classroom, share the discoveries we have made while developing a math and art class, and give you some fun problems to think about! (Received September 16, 2014)

1106-H1-2798 **Susan Goldstine*** (sgoldstine@smcm.edu) and **Ellie Baker**. *Tiling the Beaded Torus.*

A bead crochet bracelet consists of a narrow tube of seed beads sewn together to form an uninterrupted hollow torus. Creating symmetric color patterns on bead crochet bracelets is challenging because the beads form a continuous spiral along the length of a bracelet, making it exceedingly difficult to align design motifs uniformly. An elegant way to approach this aesthetic puzzle is instead to create symmetric, periodic patterns in an infinite plane of beads following simple rules that allow the patterns to wrap around bead crochet tori. In this talk, we will illustrate several powerful methods for designing bracelets tessellated by congruent tiles in multiple colors and present examples of bracelets produced by these techniques. (Received September 16, 2014)

Mathematics and Sports

1106-H5-128 **Stanley Rothman*** (stanley.rothman@quinnipiac.edu), 15 stacy ct, cheshire, CT 06410.
A New Linear Formula to Predict a Team's Winning Percentage.

Last Year at the Joint Mathematical Convention in Baltimore I presented my new linear formula for predicting a team's winning percentage (W%) based on the runs scored (RS) and runs allowed (RA) by a team. This linear formula was shown to be effective for Major League Baseball (MLB) for the years 1998-2013. Using the same techniques, I developed a linear formula for the NFL for 2002-2013 and for the NBA for 2004-2013. For MLB, W% = .000683*(RS-RA) + .50, for the NFL, W% = .001538*(PS-PA) + .50 and for the NBA, W% = .000364*(PS-PA) + .50. PS is the points scored by a team and PA is the points allowed by a team. This year's talk will first review the development of these linear formulas and why my formula for baseball and Bill James' Pythagorean Theorem of Baseball are both effective predictors of a team's W% for the years 1998-2013. In the question session after my talk last year a member of the audience remarked that my theorem would not work for the earlier years of baseball. With the help of a junior math major Alex Everett, this year's talk will use both the Chi-Square Goodness-OF-Fit Test and the Confidence Interval Test for One Mean to establish that my linear theorem and Bill James' theorem are both effective predictors for winning percentages for the years 1901-2013. (Received July 25, 2014)

1106-H5-265 **Paul R. Bouthellier*** (pbouthe@pitt.edu), 504 East Main Street, Titusville, PA 16354.
The Effect of Wind on the Flights of Golf Balls and Baseballs.

The problem that we shall examine in this talk is that of the effect of wind on the trajectory of objects such as golf balls and baseballs. We will analyze their flight trajectories, their maximum heights, and distance traveled under different wind conditions where the wind shall be implemented as a vector field in three-dimensional space. Using the mass and cross-sectional areas of the objects, the solutions of the trajectories of the objects under the effect of wind are a set of differential equations whose solution will be approximated by numerical methods. These solutions will then be rendered in 3D graphics packages allowing students to study the effects of wind on the flight paths of objects from any position and orientation in three-dimensional space. (Received August 17, 2014)

1106-H5-401 **Patrick Sullivan*** (patrick.sullivan@valpo.edu), 1900 Chapel Dr, Valparaiso, IN 46383.
The FA Cup Draw and Pairing Up Probabilities.

The FA cup is one of the most famous soccer tournaments in the world. It is open to English clubs at several levels of competition, including the top English professional leagues. The tournament begins to draw worldwide attention in the third round when the Premier League teams, some of the best professional teams in the world, join the competition. At this stage there are 64 teams in the tournament, the 20 teams from the Premier League and 44 other English teams. The teams are then randomly paired up for the games of the third round. (This is very different from most single elimination tournaments. Usually the matchups are determined by a seeding process where the strongest teams are intentionally matched up against weaker teams.) The games of the third round of the FA cup that generate the most interest are the ones in which Premier League teams are matched up against each other. I became interested in the probability distribution of the number of such games in a random draw. In this talk we will look at this distribution, its expected value and variance as well as some combinatorial results from these computations. We will also generalize to situations where other numbers of teams are involved. (Received August 27, 2014)

1106-H5-743 **Stephen J Bacinski**, **Mark J Panaggio** and **Timothy J Pennings*** (tpennings@davenport.edu), 306 E 12th Street, Holland, MI 49423.
Elvis Lives! Mathematical surprises inspired by Elvis, the Welsh corgi.

Elvis, the Welsh corgi, ostensibly showed that he could do optimization problems because, when retrieving balls thrown into Lake Michigan, he ran down the beach and then entered the water at the optimal point to get to the ball in minimum time. However, it was shown that if Elvis intended instead just to move towards the ball as quickly as possible at each point along the route (greedy algorithm), then he would still have followed the same path. In this paper we explore why these two distinct strategies would give identical paths. In particular, we determine i) when the greedy path is also the optimal path and when the optimal path is not the greedy path, ii) the effects of the starting point on the path taken - in particular, why the paths coincide when starting on the shoreline, but otherwise are different, and iii) velocity functions for which the paths coincide for all starting points. (Received September 05, 2014)

1106-H5-899 **Glenn Sidle*** (gdsidle@ncsu.edu), **John David** and **Hien Tran**. *Predicting NCAA Lacrosse Games with Cohorts of Neural Networks.* Preliminary report.

In this paper, we examine the ability of artificial neural networks to predict the outcome of NCAA Division I lacrosse games. We used statistics generally found in the box score of any lacrosse game, readily available on the internet, to create a model that predicted the spread of a game relative to the home team. Going beyond the box score, we used efficiency-based statistics (i.e. shots per possession, turnovers per possession) to create a model that was unbiased towards fast- or slow-paced teams. After creating our model, we looked at which statistics were most important for victory using a derivative-based sensitivity analysis, and we assessed the performance of our model by comparing the percentage of victors predicted correctly and the average spread error to Laxpower.com's predicted spreads. Because lacrosse is a sport that has been relatively unknown to the quantitative analysis community, many of the techniques we used to determine which statistics to use came from analogous work done in basketball. (Received September 08, 2014)

1106-H5-1110 **Reza O Abbasian*** (rabbasian@tlu.edu), Dept. of Math & CS, Texas Lutheran University, 1000 W. Court St., Seguin, TX 78155, and **John T Sieben** (jsieben@tlu.edu). *Statistical Analysis of Track and Field Events of 1988 Seoul Olympics: How Probable Are the Winning Records?* Preliminary report.

The 1988 Olympics produced highly unusual results in track and field. In fact, approximately 50% of track and field winners in Seoul would still have won 20 years later in the Beijing Olympics! The use of performance-enhancing drugs was suspected. In the April 2102 issue of the journal of Significance, Ray Stefani proposed a simple model for predicting the rate of improvements in various events and concluded that the unusual results in 1988 were most likely due to performance enhancing drugs used by a large number of athletes. In this paper we will explore the use of a more comprehensive model that will improve on Stefani's model. Specifically, we intend to use a two parameter (time and event) biased least squares approach to develop exponential regression models in four categories: sprint, mid-distance and long distance events, throwing and jumping events. We will then find the variance of the estimated error to determine the probability of the results. Furthermore, we will show that with a few assumptions, the random variable (repeat winners) can be modeled by a variant of Binomial distribution and use the model to show that the 1988 results were highly improbable. (Received September 10, 2014)

1106-H5-1322 **Sammi E Smith*** (sesmith@stetson.edu), DeLand, FL 32724, and **William W Miles** (wmiles@stetson.edu), DeLand, FL 32724. *The choking index: An Analysis of performance under pressure on the PGA tour.*

In nearly all sports, athletes are frequently placed in pressure-filled situations. The way the athlete responds to that stress is a crucial component in determining the outcome of the competition. An athlete who performs well is classified as a clutch performer, while one who does not perform well is referred to as a choker. In this presentation, we examine this phenomenon in the sport of professional golf. There are three main pressure scenarios that are considered: the pressure of the last round of a tournament, the additional pressure of the last round of a tournament when in contention, and the pressure of being close the cutline during the second round. Five separate indices were created to rank a golfer's tendency to *choke* in these situations. Using these five indices, several multiple regression models were proposed to predict the Official World Golf Ranking. In addition, a correlation analysis between the five indices and the multitude of statistics kept by the PGA tour was conducted. Based on this analysis, the indices developed represent new measures for the sport of golf and do not correlate with any current statistics kept by the PGA. (Received September 12, 2014)

1106-H5-1354 **Tim Chartier*** (tichartier@davidson.edu), Department of Math and CS, P.O. Box 6908, Davidson College, Davidson, NC 28035. *Davidson Basketball - by the numbers.*

What really counts in sports, specifically Davidson College men's basketball? Numbers are inherent in sports from tracking the score of a game to logging a player's performance. In the 1990's, Moneyball, as it has became known, revolutionized baseball. In the fall of 2013, Dr. Tim Chartier of the Department of Mathematics and Computer Science at Davidson College began analyzing, along with 4 Davidson College students, data for the men's basketball team. What statistics help and which ones might be misleading? Come see Davidson men's basketball - by the numbers. (Received September 12, 2014)

1106-H5-1403 **Kelvin Tiongson** and **Paul R. Coe*** (coepaul@dom.edu), 7900 W. Division St., River Forest, IL 60305. *Does the NBA Finals format change affect the likelihood of the higher seeded team winning the series?*

In 2014 the NBA Finals changed format from 2-3-2 (back) to 2-2-1-1-1. In this paper we will examine what affect that may have, if any, on the likelihood of winning of the higher (and lower) seeded team and the length of the series. We will use historical data from past NBA Finals to inform our conclusions. This work formed the basis of an undergraduate research project. (Received September 12, 2014)

1106-H5-1463 **Jacqueline Brannon Giles*** (jbgiles@yahoo.com), 13103 Balarama Drive, Houston, TX 77099. *Pattern Recognition and Trends of Senior AFL/NFL Players from HBCUs.* Preliminary report.

The presenter will share patterns and trends in the careers of AFL/NFL players who were trailblazers and who set expectations and standards in performance data on the playing field. Transitioning to a stable life after professional football has been a challenge for many athletes. The presenter will share information and trajectories of players who have had exceptional accomplishments in their lives after football. Some discussion of the indicators that may influence smooth transitioning from a professional football career to a career in other professions will be cited. The statistics, indicators and social-cultural characteristics of AFL/NFL players such as Mr. Clem Daniels, former Oakland Raider and successful businessman, will be compared and contrasted with other players in a similar social context and age group. A sample of AFL/NFL players who attended Historically Black Colleges and Universities will be the focus of the discussion. (Received September 13, 2014)

1106-H5-1515 **Sameer K Deshpande*** (dsameer@wharton.upenn.edu), 434 Jon M. Huntsman Hall, 3730 Walnut St, Philadelphia, PA 19104, and **Shane Jensen**. *Two New Metrics for Evaluating How NBA Players Help Their Teams Win.* Preliminary report.

Traditional NBA player evaluation metrics are usually based on scoring differential or the accumulation of points, rebounds, assists, etc. These measures treat performances with the outcome of the game still in question (e.g. tie score with five minutes left) in exactly the same way as they treat performances with the outcome of the game virtually decided (e.g. when one team leads by 30 points with one minute left). Because these methods do not consider the context in which players perform, they can result in misleading estimates of how players help their team win.

We instead use a win probability framework for evaluating NBA players. We propose a linear regression model to estimate an individual player's effect on his team's chance of winning the game, after controlling for his teammates, opponents, and potentially many other variables. Rather than treating each player's impact as a fixed constant, we adopt a Bayesian approach. We introduce two new player-evaluation metrics that balance a player's effect with variations in his performance and identify a group of high-impact players previously undervalued by metrics like Player Efficiency Rating and Real Plus/Minus. (Received September 13, 2014)

1106-H5-1542 **Jeremias Engelmann*** (jeremias.engelmann@gmail.com), Seckenheimer Gaesschen 6, 69126 Heidelberg, BW, Germany. *Estimating a players' influence on his teammates' BoxScore statistics using a modified Adjusted Plus Minus framework.*

Since RAPM (Regularized Adjustment Plus Minus) was introduced by Joe Sill at the SSAC 2011 it has been a useful tool to estimate a player's impact on his and the opponent teams' points per possession, effective FG% (eFG%), rebounding, turnovers and Free Throw rate. What RAPM can't tell us is whether a player raises (or hurts) his team's e.g. eFG% by his own shooting, or by making teammates shoot better (or worse). Through changes in the regression design matrix, and to the way the estimates are computed, I introduce a method to estimate a player's impact on his teammates' BoxScore statistics. This allows us to answer whether a player is "stealing rebounds" away from his teammates, whether (and how much) star players make it easier for their teammates to hit their shots, and to better estimate a player's BoxScore statistics when he switches teams (Received September 14, 2014)

1106-H5-1618 **E. Lee May, Jr.*** (elmay@salisbury.edu), MATH/COSC, 1101 Camden Avenue, Salisbury, MD 21801, and **Frank Van Santen**. *The Ex-Cub Factor.*

The Ex-Cub Factor is the presence, on Major League Baseball Team T, of at least three players who, at one time or another before joining T, found themselves on the roster of the Chicago Cubs. The factor was identified and named in 1981 by Ron Berler, then a columnist for the Boston Herald American. From his study of baseball statistics dating from 1946 (a year the significance of which will be explained in the talk) forward, Berler had determined that, "According to The Ex-Cub Factor, it is utterly impossible for a team with three or more ex-Cubs to win the [World] series." This talk will feature a history of the Ex-Cub Factor; the presentation of statistics on the World Series from 1946 through 2014, with an eye to how well the conjecture has fared; and some inference regarding its value as a predictor of the winner of future Series. No knowledge of baseball is necessary to understand the talk, but successful completion of a course in introductory statistics would be helpful in doing so. Consequently, the talk is accessible to undergraduates. (Received September 14, 2014)

1106-H5-1844 **Paul Britton** and **Carl Yerger***, Davidson College, Department of Mathematics & Computer Science, Davidson, NC 28035. *Boxing in Basketball: A Round-By-Round Analysis of the American College Game.*

In the last two decades, basketball coaches have increasingly relied on statistical analysis to determine teaching points for their teams. Davidson College men's basketball coach Bob McKillop divides each game into ten "rounds", with a round ending at each media timeout and at halftime, and gives his team several "round" goals for every game. Two particular goals are winning both rounds five and ten, and winning several rounds overall. How does winning more rounds affect the probability of winning the game? What other factors (such as field goal percentage, home-court advantage) are most descriptive in winning a game? Can looking at the results of multiple rounds give more information than just looking at the results of one round at a time? Come and learn about updates and new analysis obtained since a version of this research was presented in 2012 at the JMM. (Received September 15, 2014)

1106-H5-1870 **Geoff Converse*** (geoff.converse@my.simpson.edu), **Jared Grove** (jared.grove@my.simpson.edu) and **Kylie Pape** (kylie.pape@my.simpson.edu). *Maximizing Potential in a Fantasy Football Draft.*

In a fantasy sports league, the draft is the first opportunity for team managers to gain an advantage over their opponents. We created a computer program in R that can maximize a team's projected value gained from a fantasy football draft. The key feature of our program is its ability to predict when players will be taken in future rounds. This enables our team to draft the best players being considered by opposing teams in a given round and also draft players before there is a drop in value at a given position. Our program is able to learn the strategies of opposing teams as the draft progresses and therefore adjust its predictions for future rounds to increase its accuracy. Thus, even when our program starts with very little knowledge of the strategies used by the competing teams, it is able to finish with a competitive edge. We completed this project during the Dr. Albert H. & Greta A. Bryan Summer Research Program in Mathematics at Simpson College. (Received September 15, 2014)

1106-H5-2410 **Ross A Kruse*** (rokruse@davidson.edu), Box 5300, Davidson, NC 28035, and **Tim Chartier**. *Bringing Analytics to College and High School Football.*

In the fall of 2014, Dr. Tim Chartier, through the support of National Amateur Sports, created a team of four undergraduate sports analysts. The group, using sports analytics, would focus on Davidson College football, men's and women's soccer, and women's volleyball. Each member's task was 1) to apply existing analytics to his/her specific sport at the college, 2) to develop new analytics in order to aid the coaching staffs and 3) to serve as a mentor for a sports analytics group being formed in the local public school district. This fall, the high school program was piloted as an internship program to provide after school, athletic based learning opportunities and hands-on experiences for high school students in the areas of information, digital media and data analytics. In this talk, I will discuss my work as the student sports analyst for men's football. I'll detail both my work with the college team and my mentorship of high school students working with their own team. (Received September 16, 2014)

1106-H5-2528 **Ananda Manage*** (wxb001@shsu.edu), Dept Mathematics & Statistics, SHSU, Huntsville, TX 77340, and **Yang Liu** (yanliu@sw.org). *Modeling Economy Rate in Cricket: An Application of Negative Binomial Regression.*

Models for count data have been widely applied in a variety of sports. The Poisson model and negative binomial model are two common count response models. In particular, negative binomial regression model can be used to overcome the over-dispersion issue which is a common problem that arises in count data modeling. In this study, we use the negative binomial regression to model the number of runs scored within an over against different types of blowers in the sports of cricket. In particular, economy rate during the PowerPlay is a key interest. (Received September 16, 2014)

1106-H5-2530 **Jeffrey W Heath*** (jeffrey.heath@centre.edu), 600 W. Walnut St., Danville, KY 40422, and **Alexander L Cope**. *Basketball Defensive Efficiency.*

In basketball, due in large part to lack of certain in-game statistics, it is difficult to quantify individual defensive ability without making certain key assumptions. Using NBA data from 2007 to 2012, we developed a regression model that measures the points an individual defensive player allows per possession as compared to the average player. We refer to the resulting metric as Individual Defensive Efficiency. (Received September 16, 2014)

1106-H5-2531 **Reza D Noubary*** (rnoubary@bloomu.edu), Deptartment of Mathematics, Bloomsburg Univer, Bloomsburg, PA 17815. *Analysis of a Table Tennis Game: A Teaching Tool.*

A game of table tennis is analyzed using elementary concepts of calculus, probability, and linear algebra. The analysis demonstrates different modeling approaches and makes a comparison between the results under the new and the old rules of the game. It also illustrates steps involved in mathematical modeling and points out the possible expansion of it. Some hints regarding the use of materials for teaching is also included. (Received September 16, 2014)

1106-H5-2548 **Andre P Oliveira*** (aoliveira01.student@manhattan.edu), Department of Mathematics, Manhattan College, 4513 Manhattan College Parkway, Riverdale, NY 10471, and **Helene Tyler** (helene.tyler@manhattan.edu), Department of Mathematics, Manhattan College, 4513 Manhattan College Parkway, Riverdale, NY 10471. *Defensive Forwards and Offensive Backs: The 2013 Season of Manhattan College Women's Soccer.*

By viewing the players as nodes and the completed passes as weighted arrows, we conducted a network theory analysis of the fall 2013 season of the Manhattan College Women's Soccer Team. Our analysis revealed a distinctive style of play and identified some of the team's strengths and weaknesses. We established a method to quantitatively compare teams and their styles of play. Using this measure, we identified the team from the 2010 World Cup Top 16 to which the Jaspers are most similar. (Received September 17, 2014)

1106-H5-2596 **Tom Brown*** (tom.brown@enmu.edu), ENMU, Station 18, Portales, NM 88130, and **Brian Pasko** (brian.pasko@enmu.edu), ENMU, Station 18, Portales, NM 88130. *Luck in Volleyball.* Preliminary report.

The notion of 'luck' is ubiquitous in sports - from layperson discussions to commentator analysis. Often the word is used to explain an unlikely event that is highly significant. We seek to quantify luck in the particular case of NCAA Division II Lone Star Conference Women's Volleyball.

To do so, we construct a Monte Carlo simulation to play any number of matches using the data $p =$ probability that team A wins a point while serving. p is obtained by extracting play-by-play data from 110 matches over the 2011 season and then, applying the Bradley-Terry (B-T) model of pairwise comparisons.

We will define our notion of luck in sports and compare with accepted current definitions. We introduce the notion of *luck index* to normalize wins above expected to the number of games in the season by considering wins above expected in terms of the distribution of season results. This allows luck to be compared across different season lengths and different sports. (Received September 16, 2014)

1106-H5-2635 **Brian Macdonald*** (bmac@jhu.edu), Florida Panthers, 1 Panther Parkway, Sunrise, FL 33323, and **William Pulleyblank**. *Realignment in the NHL, MLB, NFL, and NBA.*

We describe a method for realigning sports leagues that is flexible, adaptive, and that enables construction of schedules that minimize travel while satisfying other criteria. Our algorithm includes (1) a method of estimating total league travel without knowing the schedule ahead of time, (2) a fast heuristic that generates thousands of possible league structures, and (3) a way to find the exact solution to the problem, which shows that our heuristic succeeds in constructing optimal solution. We also provide a way to visualize both the solutions and the algorithms used to generate the solutions. We examine a variety of scenarios for the NHL, and also apply our methods to the NBA, MLB, and NFL. We find the biggest improvements for MLB and the NFL, where adopting the best solutions would reduce league travel by about 20%. (Received September 16, 2014)

Mathematics Experiences in Business, Industry, and Government

1106-J1-990 **James H. Fife*** (jfife@ets.org), Educational Testing Service, Princeton, NJ 08541. *Automated Scoring of Graphs.*

To test a student's ability to create graphs, various interfaces have been developed that enable students to enter a graph as a response to a computer-delivered test question and various procedures have been developed to score such responses. One approach is for students to plot points and the interface then draws a curve connecting the points. The student's score is based on the points that are plotted. It is easy to score such a response if the question asks that a particular curve be drawn. But sometimes a student may be asked to draw a curve with

certain qualitative properties. To score a response to such a question, it must be determined from the points that the student has plotted if the curve drawn has the required properties.

In this presentation, I will describe work in developing the required techniques to score graph responses based on qualitative features of the graph. We compiled a list of 30 response features that could contribute to a score. For each feature, we found necessary and sufficient conditions on the plotted points for the curve to have the required feature. Scoring models were then written that could score responses based on the presence or absence of the required features. (Received September 09, 2014)

1106-J1-1192 **William P. Fox*** (wpfox@nps.edu), **Brendan Ormond** and **Alex Williams**. *Ranking terrorist as targets using a hybrid AHP-TOPSIS methodology.* Preliminary report.

We present a methodology and an example of preparing an order of merit list to rank terrorist based upon decision maker weights. We used an old terrorist data set as our base data to keep the information unclassified. This data is used to demonstrate this methodology. We perform numerical iterative criteria weight sensitivity analysis to show the effects on the model's outputs in changes in the weights. We identify the critical criterion. (Received September 11, 2014)

1106-J1-1231 **Elizabeth L Bouzarth*** (liz.bouzarth@furman.edu), **John Harris** and **Kevin Hutson**. *Math and the Mouse: Explorations of Mathematics and Science at Walt Disney World.*

Mathematics students often wonder about what they can do with their degree, and we, as professors, often struggle to find interesting real world examples to motivate students to learn. In response to this, we developed a three-week May course working with students to immerse them in applications of mathematics and science in Walt Disney World. The course focused on typical problems faced by not only Disney, but also the consumer who visits the theme parks. In addition to traditional academic lectures, the students engaged in a variety of hands on experiences (often of their own design) and got to interact with representatives from five departments within the Walt Disney Company as well as companies whose business focus is Walt Disney World, but are not employed by Disney. The course contained topics from a variety of fields, including operations research, physics, computer science, probability, statistics, and graph theory. (Received September 11, 2014)

1106-J1-1267 **Stephanie Fitchett*** (sfitchett@neptuneinc.org). *Is my indoor air affected by vapor intrusion? If so, is it dangerous?*

Radon is the most common vapor intrusion concern. Other compounds can enter a building in a similar way, through the foundation, and a home may be especially susceptible to problematic vapor intrusion if it sits over a contaminated plume of groundwater. While testing for radon is easy and inexpensive, testing for other contaminants can be quite expensive, and concentrations can vary dramatically depending on building construction, geographic location, and weather conditions. Thus, while it would be valuable to be able to determine if a building has a vapor intrusion problem based on the results of a single indoor air sample taken over a short duration, making such a determination is challenging. This talk discusses a statistically based decision analysis tool that helps one to estimate the extent to which a single indoor air sample may be indicative of vapor intrusion. The tool further provides estimates for the likelihood that long-term average concentrations – which are not measured directly, but are modeled and are relevant to health risks – are high enough to raise concerns. The working team includes risk analysts, mathematicians, statisticians, and web programmers at a private consulting company. (Received September 11, 2014)

1106-J1-1653 **Thomas Höft*** (hoft@stthomas.edu), University of St. Thomas, St. Paul, MN. *Noise removal in Fourier transform profilometry.*

We present a new noise removal method for a 3-D imaging system used in industry for biometric identification. In Fourier transform profilometry, an optical system projects light with a sinusoidally-varying pattern on a 3-D surface, such as a face, and records the resulting image. The depth profile of the surface modulates the sinusoid; the phase of the inverse Fourier transform of the modulated signal's spectrum is proportional to the imaged 3-D surface. However, the spectrum of the modulated sinusoid is overlapped by other components of the spectrum, which prevents accurate reconstruction of the surface. This new method uses an otherwise discarded portion of the spectrum to estimate the obscuring spectral components and filter them out. Additionally, the method reduces additive white noise. Surfaces reconstructed using this denoising method have increased precision and suffer from fewer aberrations, enabling biometric identification with greater sucess rates. We present the method along with simulated results. (Received September 14, 2014)

1106-J1-1798 **Candice Rockell Gerster*** (crgerstner@hotmail.com). *The Future of Image/Video Feature Detection.*

In computer vision and image processing, feature detection is the process of determining if a pixel is an "interesting" part of an image. This is done by utilizing a feature descriptor algorithm such as Scale-Invariant Feature Transform (or SIFT), Histogram of Gradients (or HOG), or Binary Robust Independent Elementary Features (or BRIEF) to name a few. However, recent research into using convolutional neural networks (CNN) for image/video feature detection have prompted discussion and research on whether CNN will outperform these descriptors. This talk will discuss the basics of current feature descriptors and the long term uses of each, with an emphasis on image/video feature detection. (Received September 15, 2014)

1106-J1-2327 **Adam H. Fuller*** (afuller7@math.unl.edu), Department of Mathematics, University of Nebraska, 203 Avery Hall, PO BOX 880130, Lincoln, NE 68588-0130, and **Jeremy Trageser**. *Math in the City.*

Math in the City is a hands-on modelling course for undergraduates. Each year we team up with a local business or local government agency to provide the students with real data to work with.

In this talk I will give an overview of the course, as well as talk about the specifics of this years projects. Our partner this year is Beehive Industries. (Received September 16, 2014)

1106-J1-2668 **Michelle Ghrist*** (michelle.ghrist@usafa.edu), HQ USAFA/DFMS, Dept of Mathematical Sciences, 2354 Fairchild Hall, Suite 6D2A, USAF Academy, CO 80840. *The Adventures of an Academic Working as an Analyst for the Air Force.*

For my most recent sabbatical, I worked full-time for Air Force Space Command at Peterson Air Force Base as an analyst. For a year, I was immersed in several complex projects which involved applying mathematics to problems of real-world interest. In this talk, I discuss the three main projects on which I worked; one involved examining the numerical methods that are used to predict orbital trajectories and two involved modeling missile trajectories. I also reflect on how my experience was affected by and influenced my life as an educator. (Received September 16, 2014)

1106-J1-2776 **Erik Bates*** (ewbates@stanford.edu), 137 Running Farm Lane, Apt. 110, Stanford, CA 94305, and **Anthony Gusman**, **Stephanie Sanchez** and **Sarah Verros**. *Long-term crime forecasting and setting crime reduction targets.*

We investigate the potential of the Los Angeles Police Department to forecast future crime rates along time scales of months to years. Department officials set annual crime reduction goals based on a constant percent decrease from the previous year's citywide crime levels. While this procedure may accurately reflect a general decline in total crime, it does not consider any long-term trends or seasonality in crime data. The potential consequences include inaccurate performance assessments and non-optimal allocation of department resources. This study develops models that extract long-term and seasonal components in Los Angeles crime rates and use the extracted components to forecast future crime rates. The resulting predictions are compared against both historically observed crime rates and the projections made with the department's percent decrease methodology. (Received September 16, 2014)

1106-J1-2942 **Omayra Ortega*** (omayra.ortega@asu.edu), **Gloria Crispino** and **Catherine Comiskey**. *Methodologies for Statistical Analysis of the Effects of Drug Use on Hidden Populations.*

Drug users and their children are predominantly a hidden population, for which accurate prevalence estimates have to be computed with indirect methods, such as capture-recapture models and rely on multiple data sources that often do not align. Therefore, finding these children and any negative health outcomes is a multi-layer issue. Potential data sources are intrinsically related to the data sources of their parents and carry at least the same complexities. The main focus of this work is on the need for such types of research given the lack of evidence, the proposed methods that may be used, and types of data sources countries may have in general. Such a study has been commissioned by the National Advisory Committee on Drugs and Alcohol in Ireland and results will be forthcoming next year. (Received September 17, 2014)

Original Sources and Archives in the Classroom

1106-J5-63 **Amy Ackerberg-Hastings** and **Amy Shell-Gellasch***, 14505 Faraday Dr, Rockville, MD 20853. *Mathematical Devices at the Smithsonian: Ideas for using digital collections in the classroom.* Preliminary report.

Many museums have collections of mathematical and scientific objects. In the past, these collections have often been inaccessible to the general public. However, repositories around the world are now in the process of digitizing their collections and making them available online. The Smithsonian Institution has an extensive collection of mathematical and scientific devices and models housed throughout many of its 19 museums. Those items are currently being digitized and made available via institutional websites, including http://americanhistory.si.edu/collections/object-groups/ and http://collections.si.edu. In this talk we will present an overview of the Smithsonian's online collections and suggest ideas for using these collections in the mathematics classroom. (Received June 09, 2014)

1106-J5-481 **Walter Jacob*** (walter.jacob@temple.edu). *A novel approach to the integral of* $\csc x$ *inspired by James Gregory's* Vera Quadratura.

The typical approach to the integral of the cosecant function encountered by calculus students is often frustratingly unintuitive. This strategy asks the student to perform a multiplication that is not immediately obvious and in fact requires one to know the answer in advance. As a result, even a student who appreciates the cleverness of this trick is often left wondering how they might have discovered such a solution on their own. In James Gregory's 1667 book Vera Circuli et Hyperbolae Quadratura, he proves a simple but surprising property of the hyperbola that allows for a much more intuitive approach to the integral of $\csc x$. In our presentation, we will explain how the translation of Gregory's book led to this observation. (Received August 29, 2014)

1106-J5-1252 **Daniel E Otero*** (otero@xavier.edu), Dept of Mathematics & Computer Science, Xavier University, Hinkle 104, 3800 Victory Parkway, Cincinnati, OH 45207-4441. *Hindu sines, Persian tangents, and European triangles: teaching trigonometry with original sources.* Preliminary report.

In an effort to enliven a traditional classroom treatment of the fundamental principles of trigonometry, three mini-lessons are presented that give students a sense of the wide scope of the history and context of the subject. These lessons are built around three texts: from the sixth century, Varāhamihira's *Pañcasiddhāntikā* (*Five Systems*), an early table of sines; from the eleventh century, al-Bīrūnī's *Kitāb fī ifrād al-maqāl fī umr al-ẓilā* (*Exhaustive Treatise on Shadows*), an early version of tangent and cotangent values; and from the sixteenth century, Regiomontanus' *De triangulis omnimodis* (*On Triangles of All Kinds*), the first systematic treatment of trigonometry as a geometric theory. Comments will also be shared regarding effective pedagogy in the use with today's undergraduate students of primary source texts whose cultural distance from modern readers is high. (Received September 11, 2014)

1106-J5-1853 **Toke Knudsen*** (toke.knudsen@oneonta.edu), Department of Math., Comp. Sci., and Stat., SUNY Oneonta, 108 Ravine Parkway, Oneonta, NY 13820. *Historical Mathematics Sources at SUNY Oneonta.*

In the Special Collections of the State University of New York at Oneonta is found a large collection of items relevant to the history of mathematics. More specifically, the collection consists of over 220 textbooks dating from the 1780s; diaries of mathematics faculty members; course material produced by mathematics faculty members; a few student notebooks from the beginning of the 20th century; and reports from the student teaching of students at the college from the same time. Over several semesters I have incorporated the material in the collection into my teaching of the course *Introduction to the History of Mathematics*, where the students (mostly future educators) explore the collection and write papers on the material as part of the course. This hands-on approach and direct engagement with historical sources has been received very positively by the students. The talk will detail my work with the collection and my experiences when utilizing it in my teaching. (Received September 15, 2014)

1106-J5-1953 **Matthew J Haines*** (haines@augsburg.edu), Augsburg College, CB 28, Mathematics Department, 2211 Riverside Ave, Minneapolis, MN 55454. *An Activity Utilizing the Smithsonian's Transcription Center.* Preliminary report.

The Smithsonian's Transcription Center recently invited the public to help transcribe documents in its collection. A History of Mathematics course activity designed for students to assist in the transcription of Mary Smith's

Commonplace Book Concerning Science and Mathematics from the late 1700s will be presented. (Received September 15, 2014)

1106-J5-2540 **Van Herd*** (herd@austin.utexas.edu), College of Undergraduate Studies, University of Texas at Austin, Austin, TX 78712. *The Dead Mathematicians Society: Instruction, Innovation and Inspiration in Developmental Mathematics from the University Archives.*

As a mathematics instructor at the University of Texas at Austin, the author also has a background in Library and Information Studies, with an emphasis on mathematics librarianship and bibliographic description. In this session will be presented specific lessons and accompanying analyses of developmental mathematics courses the author regularly teaches in which several days of each semester are spent in the archives of the Harry Ransom Center for the Humanities (HRC). The HRC has many holdings in the History of Mathematics. In these sessions, students are presented with original mathematics sources such as Newton and Herschel in a "humanities" setting that teaches by allowing students to see the historical development of mathematical concepts. The author will also suggest means, such as the EEBO database, for instructors without a proximal mathematics archives to implement these instructional methods and measures. (Received September 16, 2014)

Perspectives and Experiences on Mentoring Undergraduate Students in Research

1106-K1-49 **Joe A. Stickles, Jr.*** (jstickles@millikin.edu), 1184 W. Main St., Decatur, IL 62522. *All It Takes Is One.*

Do you have that one particularly inquisitive student who wants to dig deeper into the graph theory learned in a discrete mathematics class, conduct an analysis of your institution's enrollment trends using techniques just learned in a statistics class, or write a computer simulation of a game using Markov chains? Then you have the foundation to start a healthy and productive undergraduate research program! In this talk we will discuss how just one student's inquisitive nature sparked a culture of expectation at Millikin University. Besides detailing the undergraduate research program at Millikin, we will provide insight on where to look for tractable problems, how to integrate student work into your research agenda, and how to achieve balance for both you and your students. We will also share several success stories, such as award-winning posters, national conference presentations, published journal articles, participation in summer programs, and graduate school acceptance. (Received May 28, 2014)

1106-K1-61 **Bogdan D. Suceava*** (bsuceava@fullerton.edu), 800 N State College Blvd, 154 McCarthy Hall, Department of Mathematics CSUF, Fullerton, CA 92834-6850. *New Curvature Invariants: a Research Topic Suitable to Undergraduate Students.*

In the last two decades, there have been important advances in the study of new curvature invariants. A natural question is to investigate which fundamental algebraic inequalities yield meaningful consequences in terms of curvature. This research topic is suitable to undergraduate students familiar with fundamental inequalities with real numbers; ideally, the students' background should include a one semester long course on the differential geometry of curves and surfaces. We will show how this idea produced publishable works, e.g. 'New Curvature Inequalities for Hypersurfaces in the Euclidean Ambient Space', by C. T. R. Conley, R. Etnyre, B. Gardener, L.H. Odom, and B.D. Suceava, Taiwanese J. Math., 17 (2013), 885-895. (Received June 06, 2014)

1106-K1-234 **Joe DeMaio*** (jdemaio@kennesaw.edu). *Cycling Undergraduate Students through Graph Theory Research.* Preliminary report.

A significant hurdle when including undergraduate students in mathematical research is providing a problem which is quickly understood and offers the opportunity for progress without years of preparatory study. Graph Theory lends itself well to simply posed questions whose general solutions are NP-complete. By including additional constraints these same problems transform themselves into suitable undergraduate research projects. In this talk, I will share my experiences directing undergraduate research in the graph theoretic areas of domination, independence and Hamiltonian cycles. (Received August 13, 2014)

1106-K1-241 **Jordan Schettler*** (jcs@math.ucsb.edu). *Ramanujan and the Icosahedron: A Research Experience with Many Faces.*

In the winter and spring quarters of 2013, I led a group of five undergraduate math majors in discovering the deep connection between some famous continued fraction identities of Ramanujan and the Platonic solid with twenty faces. The content was multifaceted: historical, combinatorial, algebraic, geometric, and complex analytic. I will discuss how the project was conceived, finding students, the organizational challenges involved, and the outcomes. (Received August 13, 2014)

1106-K1-422 **Jonathan K. Hodge***, Department of Mathematics, Grand Valley State University, Allendale, MI 49401. *A Holistic Approach to Mentoring Undergraduate Research in Mathematics.* Preliminary report.

Most undergraduate research projects in mathematics aim to provide students with an opportunity to engage new mathematical ideas and perhaps even make their own contributions to the field of mathematics. Apart from the actual mathematical content, however, undergraduate research also provides a unique context for students to develop their communication skills, collaborate with diverse peers, and participate in the broader mathematical community. In this talk, I will focus on these broader skills and experiences, discussing strategies for mentoring holistic research experiences that promote mathematical, professional, and personal growth. (Received August 27, 2014)

1106-K1-494 **Laura Taalman*** (laurataalman@gmail.com). *Kick-starting undergraduate research.*

Undergraduate research is so vital that every math major - especially those interested in pursuing graduate school - should participate in some kind of research activity. However, not every student is ready to jump into undergraduate research, and not every department has programs in place to support that research. In this talk we will discuss ways to solve both of these problems through the use of 1-credit semester courses, undergraduate research conferences, internal summer programs, and even innovative 3D-printing projects that can serve as jumping off points for students and departments alike. Early exposure to mathematical research can help inspire students to continue in mathematics as well as make them more competitive for acceptance into future research projects. In turn, successful introductory programs can help bolster a department's bid to obtain university or national funding for larger undergraduate research programs. We will review specific examples of piloting and mentoring such early undergraduate research programs and examine their effect on future student and departmental activities. (Received August 30, 2014)

1106-K1-512 **Irina Seceleanu*** (iseceleanu@bridgew.edu), Brdigewater State University, 131 Summer St., Bridgewater, MA 02325. *Mentoring an Undergraduate Research Project: A Mathematical Model of Glacier Retreat.*

In this talk we present aspects of the very rewarding but challenging experience of mentoring an interdisciplinary undergraduate research project on the retreat of glaciers in a changing climate. The focus of the project was to create a mathematical model to study the effects of different climatic factors on glacier area, and to simulate the evolution of glaciers using different projections of global temperature over the next century. In this talk we emphasize the timeline of the project, from recruiting the student and selecting a suitable topic to disseminating the results through publication and conference presentations, and discuss overcoming the various challenges encountered along the way. We highlight ways to keep students on-track and set appropriate expectations, and discuss how to create a supportive learning environment for students that will help them reach their full potential. Moreover, we describe the implications for faculty directing undergraduate research projects and present a perspective on this multifaceted enterprise. (Received September 07, 2014)

1106-K1-669 **Jonathan Needleman*** (needlejs@lemoyne.edu). *Egalitarian research: How to have successful research experiences for students of all levels.*

Every math major should be able to do mathematics research. The trick is finding the right project for the student. This talk will focus on three questions. What makes a good project? How do I find the right project for the student? And finally, how do I mentor struggling math students in research? (Received September 04, 2014)

1106-K1-690 **Suzanne Lenhart*** (lenhart@math.utk.edu), University of Tennessee, Dept. of Math. 227 Ayres Hall, 1403 Circle Drive, Knoxville, TN 37996-1320, and **Kelly Sturner** (ksturner@nimbios.org), National Institute for Math. & Bio. Synthesis, University of Tennessee, 1122 Volunteer Blvd. Suite 106, Knoxville, TN 37996-3410. *Mentoring Collaboration for REU Groups at the Interface of Biology and Mathematics.*

Developing collaboration skills is key for both the 21st century mathematician- and scientist-in-training. We discuss the practices and activities we use for our undergraduate researchers who, in a short span of time, must learn to work together with other students and mentors from different cultural and disciplinary backgrounds on interdisciplinary projects that involve modeling, data and biological questions. Students learn to understand the value of different contributions to a common goal, negotiating roles, and the real challenges and benefits of working with a diverse team. We use explicit instruction in the nature of science and opportunities for individual and group reflection and self-evaluation to facilitate collaborative skill-building and a functional group dynamic. (Received September 04, 2014)

1106-K1-763 **Aklilu Zeleke*** (zeleke@stt.msu.edu). *Starting and Sustaining an Undergraduate Research Program: The SURIEM/REM Experience at Michigan State University (MSU).*

Mentoring undergraduate students in research is both rewarding and challenging. In this talk we present how we established a summer REU and a year long undergraduate research program at MSU. We outline strategies for recruitment, problem selection, matching undergraduate researchers with projects, finding financial resources, and developing environments that cultivate interest and independence in doing research. Using the SURIEM/REM experience from 2010-2014, examples of challenges and solutions will be presented. (Received September 06, 2014)

1106-K1-999 **Hyunju Oh*** (hoh@bennett.edu), 900E. Washington Street, Department of Mathematics/Computer Science, Bennett College, Greensboro, NC 27401, and **Jan Rychtar** (rychtar@uncg.edu). *Co-Mentoring for the National Research Experience for Undergraduates Program in two Institutions.*

In this talk, we will present our two years of experiences in the "National Research Experience for Undergraduates Program" funded by Mathematical Association of America. Jan Rychtar at the University of North Carolina at Greensboro and Hyunju Oh at the Bennett College co-directed students' projects in "Game Theory and Applications" during the six weeks each summer 2013 and 2014. We will report how we support African-American female undergraduate students from Bennett College in research experience and the students' achievements, and how we collaborate between two project directors in two different institutions. (Received September 09, 2014)

1106-K1-1008 **William W. Johnston*** (bwjohnst@butler.edu), Butler University, 4600 Sunset Ave., Indianapolis, IN 46208. *Mathematics Summer Research Camp: A Report.*

This presentation reports on the intended outcomes, details of design, costs, and multiple positive results of an undergraduate research experience for majors that was held this past summer. This Mathematics Research Camp (MRC) at Butler University provided an eight-day intensive introduction for mathematics majors on how to discover new mathematics. Any undergraduate mathematics department could implement such a design for its majors with similar positive effects. The report will include data on measurable outcomes, providing evidence of a significant increase in undergraduate research activity as a result of MRC. (Received September 09, 2014)

1106-K1-1276 **Christopher E Brown*** (cbrown@callutheran.edu), Christopher E Brown, California Lutheran University, #3750, 60 West Olsen Road, Thousand Oaks, CA 91360, and **Grady Hanrahan** and **Craig Reinhart**. *Improving mathematical undergraduate research at a small liberal arts college through scientific computing.*

Undergraduate research (UR) at a small liberal arts college is a constant struggle. Limits on faculty time, institutional resources, and student availability can challenge even the most committed UR mentors. At our institution, an existing culture of UR-as-lab-science presents additional difficulties for mathematics. In 2011-2012, we developed and implemented a program in scientific computing to foster undergraduate research in mathematics and mathematically flavored research in partner disciplines. We discuss the successes and challenges of developing and maintaining the program, the interaction of the program's staff and students with faculty and administration, and student perspectives and outcomes during the program and two years afterwards. (Received September 11, 2014)

1106-K1-1337 **Chad Awtrey*** (cawtrey@elon.edu). *One approach to researching, presenting, and publishing with undergraduate pure math majors.*

The goal of this talk is to describe the speaker's recent collaborations with undergraduates on projects related to computational Galois theory. Included are discussions of the following: recruiting students, funding sources, tips for beginning the writing process, dissemination outlets, a description of a recent project, and a summary of students' achievements and post-baccalaureate plans. (Received September 12, 2014)

1106-K1-1416 **Min-Lin Lo*** (mlo@csusb.edu). *The less you teach, the more students learn!*

I have had the opportunity to mentor undergraduate summer research groups of 4-6 people for the past several summers under two grants. One of which is from MAA's NREUP grant which supports the participation of mathematics undergraduates from underrepresented groups in research experiences to increase their interest in advanced degrees and careers in mathematics. The other is from NSF's PRISM grant which targeted at entry level undergraduate students from all areas to encourage students to stay in or convert to STEM majors. In this talk, I will share my REU program structure (and the difference between the two programs) as well as challenges faced and lesson learned from these programs. (Received September 12, 2014)

1106-K1-1708 **Vesta Coufal*** (coufal@gonzaga.edu). *A different way to begin.*

As a young topologist wanting to do research with undergraduates, I was at a loss about how to get started. I knew no topics from my graduate work that would be accessible to students at the small liberal arts school at which I was teaching. I sought and followed the advice of experts, but things didn't go so well. So I backed away from the idea of doing research with undergraduates. Instead, I started reading an undergraduate level book that interested me, and stumbled on a different, and quite successful way to build an undergraduate research program. I worked with students every step of the way. The experience contributed to their success, both as undergraduates and beyond. (Received September 15, 2014)

1106-K1-1789 **Dominic Klyve*** (klyved@cwu.edu). *Spotlight on undergraduate research – engaging the media.*

This talk will describe efforts by the speaker to engage and motivate students in undergraduate research by giving them a large audience and engaging the media in advertising their work. After describing some partially successful early attempts, the talk will go on to discuss a recent event in which undergraduate research in mathematics became, briefly, a "hot news item" in Central Washington. The talk will conclude with some thoughts about how these experiences can be recreated and improved upon. (Received September 15, 2014)

1106-K1-2010 **Violeta Vasilevska*** (violeta.vasilevska@uvu.edu), 800 W University Parkway, Orem, UT 84058. *Implementing CURM Model in Mentoring Undergraduate Research.* Preliminary report.

In 2013 I received one of the Center for Undergraduate Research in Mathematics (CURM) mini-grants, and as a result I started an undergraduate research group at Utah Valley University. Since then, I have been working with undergraduate math majors on various undergraduate research projects. In this talk, I will discuss a few aspects of this work that follows the CURM model. I'll share how this research has been conducted, the role of being a mentor, the challenges and how to overcome them. In addition, I will discuss the impact of the undergraduate research on student learning, as well as the effect on the students, such as the successes and failures, and how to deal with them. (Received September 15, 2014)

1106-K1-2057 **Benjamin Hutz*** (bhutz@fit.edu), 150 W. University Blvd, Melbourne, FL 32901. *Identifying Topics for Undergraduate Research Projects.* Preliminary report.

Student research projects provide an opportunity for students to work on more open-ended, less well-defined problems and can be a valuable aid to their education. However, choosing problems that are of an appropriate scope and difficulty can be challenging. In this talk I will discuss the success I have had with projects involving the computer algebra system Sage. The students have both been students planning to attend graduate school and students planning to enter industry. Their projects have ranged from purely algorithmic implementation problems to theoretical investigations aided by computational examples. I will discuss more generally how to choose an appropriate topic involving computation and how to identify students that succeed with these types of projects. (Received September 15, 2014)

1106-K1-2193 **Christina Eubanks-Turner*** (ceturner@lmu.edu), **Patricia Beaulieu**, **Nabendu Pal** and **Aghalaya Vatsala**. *Lessons Learned from the Pilot Project 'Smooth Transition for Advancement to Graduate Education (STAGE) for Underrepresented Students in Mathematical Sciences'.*

'Smooth Transition for Advancement to Graduate Education (STAGE) for Underrepresented Students in Mathematical Sciences is a Pilot Project' which was funded by the National Science Foundation for a three year period. In this talk we share our experience in implementing the project, lessons learned, and give some STAGE Scholar success stories. (Received September 16, 2014)

1106-K1-2233 **Debra L Mimbs*** (dmimbs@leeuniversity.edu), 1120 North Ocoee Street, Cleveland, TN 37320. *Assessing Undergraduate Research Through Journaling.*

It is necessary while mentoring students in undergraduate research to conduct assessments in order to determine how well the research experience is progressing. One such assessment tool I have found particularly useful is journaling. Journaling may be used both as a formative assessment tool and as a summative assessment tool. This talk discusses the process of introducing journals into a mentoring relationship and using them to inform interactions with students. (Received September 16, 2014)

1106-K1-2264 **Yun Lu*** (lu@kutztown.edu), Mathematics Department, Kutztown University of PA, Kutztown, PA 19530. *My Experience about How to Start the Undergraduate Research.*

In this talk, I will share my experience on mentoring undergraduate research. In particular, I will talk about how to start the undergraduate research in our school, which has no graduate program in mathematics. I will focus on how to choose appropriate topics, how to attract students with appropriate background, as well as other aspects to get the undergraduate research started. I will talk about the successes and challenges that occurred if time allows. (Received September 16, 2014)

1106-K1-2363 **Joseph Rusinko*** (rusinkoj@winthrop.edu), **Kristen Abernathy**, **Zach Abernathy**, **Beth Costner** and **Kristi Westover**. *Developing an REU at a Primarily Undergraduate Institution.*

We share our experience in developing a culture of undergraduate research at Winthrop University over a five year period. We provide our prospective on how to develop and fund an undergraduate research program at a resource limited, teaching focused institution. As special emphasis will be placed on how our mentoring strategies developed over time to best accommodate changing student needs. (Received September 16, 2014)

1106-K1-2459 **Zhixiong Chen*** (zchen@njcu.edu), 2039 Kennedy Blvd, Jersey City, NJ 07305, and **Yi Ding** (yding@njcu.edu), 2039 Kennedy Blvd, Jersey City, NJ 07305. *Undergraduate Research in an Urban Minority University.*

For the past a few years we have conducted research intensively with our undergraduate students. The research projects focus on topics combining applied mathematics with the environmental sciences, biological sciences, chemical engineering, etc. The students' research projects were presented in our university, MAA NJ section meetings and the JMM meetings. During the whole process, we gained extensive hands-on experience by selecting the appropriate students, deciding on research topics, motivating and interacting with the students, balancing between encouraging independent study and offering advice, and guiding the students to present their results clearly. We will share our strategies and thoughts from this experience, especially for schools with high percentage of minorities. (Received September 16, 2014)

1106-K1-2493 **Theodore J Wendt*** (twendt@carroll.edu), Department of Mathematics, Carroll College, 1601 N. Benton, Helena, MT 59625, and **Benjamin Galluzzo**. *The 24-Hour Mathematical Modeling Challenge: A Gateway to Undergraduate Research.*

In this talk, we describe the 24-hour Mathematical Modeling Challenge (24MMC), an extracurricular mathematical modeling event that exposes undergraduate students to mathematics as it can be applied to real-world problem solving. We give an outline of the rules, structure, and outcomes from the contest, with particular focus on how this contest has been effectively used by students as a gateway into undergraduate research. Our experiences have shown that participation in a 24MMC or similar event helps to identify potential undergraduate research students, provide ideas for undergraduate projects in applied mathematics, and promote resourcefulness and independent research among students. (Received September 16, 2014)

1106-K1-2513 **Brittany Smith Baum*** (bds2x@mtmail.mtsu.edu), **Jesse Beck**, **Ginger Holmes Rowell**, **D. Christopher Stephens**, **Thomas Cheatham**, **Jennifer Yantz** and **Donald Nelson**. *Introductory Research Experiences at the End of the First Year of College.*

Universities across the nation are working to increase retention rates for STEM majors. As part of Middle Tennessee State University's (MTSU's) initiative to improve retention of at-risk STEM majors, they recruit first-time, full-time freshmen STEM majors with mathematics ACT scores of 19 to 23 to participate in MTSU's "Mathematics as a FirstSTEP to Success in STEM" project (supported National Science Foundation grant #0969571). One component of MTSU's FirstSTEP program is an introductory, team-based, research experience held at the end of the students' first year of college. FirstSTEP's introductory research experience is a three-week, inquiry-based, intense exploration led by faculty. This presentation overviews the FirstSTEP research approach and demonstrates that introductory, early research experiences can be successful for mathematics projects. At the end of their freshman year, mathematics students can develop a foundation to conduct mathematical research, increase depth of content knowledge, and improve confidence in their technical abilities. As the FirstSTEP participants move toward graduation, we are studying the effects of this project on retention as compared to a control group. (Received September 16, 2014)

1106-K1-2643 **Justin Lanier*** (justin.lanier@gmail.com). *Research Experiences for Secondary Teachers.*

While robust research opportunities exist for undergraduates in mathematics, few such opportunities exist for pre-service and in-service secondary teachers. Yet research experiences for teachers can greatly impact their teaching practices, their mathematical self-perceptions, and their capacities for representing mathematics to their students. This talk will highlight the work being done at several research experiences for teachers around the country, including at Illinois State, Notre Dame, and Boston University. The programs' impact on participating teachers will be shared, both from first-hand experience and from interviews of participants. The talk will conclude with an outlining of steps to promote the creation of further research opportunities for secondary teachers. (Received September 16, 2014)

1106-K1-2673 **Michael A. Karls*** (mkarls@bsu.edu), Department of Mathematical Sciences, Ball State University, Muncie, IN 47306. *An Applied Project-Driven Approach to Undergraduate Research Experiences.*

In 1999 I was approached by a Ball State student to be an Honors Thesis advisor. Having no clue what constituted an appropriate honors thesis project, I gave the student an open-ended problem to consider – modeling heat flow in a thermos. Not only did the student complete his honors thesis, but the resulting work led to a refereed journal article and opened the door to a very successful series of collaborative undergraduate research projects. All of the problems have the following in common – they are simple to state, open-ended, student driven, mathematically significant, rely on student insight, and require a substantial amount of work on both the student's and my part. Several of these projects have led to a refereed publication that could be used to illustrate topics taught in the undergraduate curriculum. We will look at the process I have developed for this type of research, what works and what doesn't work, and touch on some of the topics explored, namely heat flow, cryptography, and diving boards. (Received September 16, 2014)

1106-K1-2757 **Shannon R. Lockard*** (slockard@bridgew.edu). *Mentoring Student Mentors.*

Bridgewater State University has several programs intended to engage students in undergraduate research. The Adrian Tinsley Program (ATP) is one of the largest of these programs and provides support for undergraduates to work on a research project for 10 weeks during the summer under the mentorship of a faculty member. Another notable program brings incoming STEM majors to campus for three weeks during the summer before their freshman year. While these students are on campus, they are matched with an ATP student, completing their own research project that is related to the ATP student's project. This experience is a profound one for all students involved: the incoming freshman engage in research before they even start college and the ATP students, further along in their education and already involved in research, have the opportunity to be a research mentor to other students. In this talk, I will describe my experiences mentoring students in these partnerships over the past two summers, focusing mainly on the students in the ATP program and their experiences mentoring other students. I will include comments from all students involved describing the impact of the summer program on their education and career goals. (Received September 16, 2014)

1106-K1-2762 **Mehdi Razzaghi*** (mrazzagh@bloomu.edu), Dept. of Mathematics, Bloomsburg University, Bloomsburg, PA 17815. *A Data Mining Research Project and Its Benefits.* Preliminary report.

A research project was submitted for internal grant competition within the Pennsylvania State System of Higher Education. It involves outcome classification in data mining application. An undergraduate student with a major role in the project is currently working on the project. Here we discuss the benefits to the student and how the student is learning a multitude of skills by working on different aspects of the project. (Received September 16, 2014)

1106-K1-2777 **Shenglan Yuan***, 31-10 Thomson Ave., Long Island City, NY 11101. *Origami, Geometry and Undergraduate Research.* Preliminary report.

In this talk, we'll describe a case study about an origami project used for undergraduate research at the community college level. We'll show how the geometric nature of origami helped an undergraduate student come to know the essence of how mathematical research works. We'll also address how to find appropriate questions and projects for students to tackle. (Received September 16, 2014)

1106-K1-2801 **Ryan Brown**, **Marcela Chiorescu** and **Darin Mohr*** (darin.mohr@gcsu.edu). *Building Capacity for a Research Rich Curriculum in Mathematics at Georgia College.* Preliminary report.

The Department of Mathematics has recently revised its curriculum to make undergraduate research a prominent feature of the major. We require all undergraduate students to complete a year-long research project, submit a written report, and give a presentation at our department's annual capstone day. Before we could implement a robust research experience, we first had to build institutional capacity to support our students and faculty to ensure its sustainability. This presentation will describe the roadmap we developed, the lessons we learned and an outline of our plans moving forward as we implement the next phase of our curriculum building. (Received September 16, 2014)

1106-K1-2895 **Zsuzsanna Szaniszlo*** (zsuzsanna.szaniszlo@valpo.edu). *Why? and How? Undergraduate Research and its Benefits.*

In this presentation I give a personal perspective on undergraduate research. I describe different possible programs in details and talk about how they benefited my career in the past two decades. I hope to convey that undergraduate research is possible in any college environment and I will try to give some concrete suggestions on how to start and how to grow a program. (Received September 17, 2014)

Program and Assessment Implications of Common Core State Standards Implementation

1106-K5-105 **Ruthmae Sears*** (ruthmaesears@usf.edu), University of South Florida, 4202 E. Fowler Ave., EDU105, Tampa, FL 33620, **Burgos Fernando** (fburgos@usf.edu), University of South Florida, Department of Mathematics & Statistics, 4202 East Fowler Ave, Tampa, FL 33620, and **Rebecca Wooten** (rwooten@usf.edu), University of South Florida, Department of Mathematics & Statistics, 4202 East Fowler Ave, Tampa, FL 33620. *Collaborative Effort to Address Content and Practice Standards in a Middle School Mathematics Teacher Preparation Program.* Preliminary report.

In this presentation, we will discuss a collaborative effort between faculty members in the College of Education and the Department of Mathematics and Statistics, to develop a middle school mathematics teacher preparation program, which aligns with the Florida's adaptation of the Common Core Mathematics Content Standards, and Standards for Mathematical Practice. The goal of the collaboration was to foster preservice teachers development of an advance understanding of elementary mathematics, and to cultivate mathematical processes and practices during the enacted curriculum. Hence, a mathematics educator and two mathematicians co-planned and co-taught lessons, to provide opportunities for preservice teachers to engage in productive struggles with mathematics.

During the co-planning, syllabi for the three courses (Number Connections, Probability and Statistics and Mathematics Methods for Middle Grades) were revised to address concepts that are deemed vital to facilitate preservice teachers' mathematical understanding, strengthen their ability to construct arguments and promote their engagement in mathematical reasoning.

Hence, we will describe the program, the co-planning initiative and its complexities, and changes to the syllabus and faculty's instructional practices. (Received July 16, 2014)

1106-K5-212 **Kathryn Ernie*** (kathryn.t.ernie@uwrf.edu), **Erick Hofacker**, **Sherrie Serros** and **Barb Bennie**. *Impacting Change in the Common Core Era through a Mathematics Partnership.*

In 2012 we were awarded a three-year mathematics partnership grant between UW-River Falls, UW-Eau Claire, and the Rice Lake Area School District. Over our two-plus years working on the project over 50 middle school and high school math teachers from 16 districts in Western Wisconsin have participated. The main goal of the project is to better prepare teachers for implementation of the standards, especially with areas that have not been emphasized by past standards. Our main focus has been in the areas of: modeling, communication, representation, reasoning, and sense making. Data has been collected on teachers and their students through surveys, content exams, and observations to show the impact of the project. Surveys have focused on the implementation of the practice standards, as well as with expertise with individual content standards. Pre- and post- content exams have been given to teachers (and control group) within each of the different focus areas. Pre- and post- exams have been given to their students (and control group) that focuses on a specific standard or set of standards. Teachers have created or chosen various tasks to meet the standards. PIs have conducted classroom observations to observe implementation and impact. Preliminary results will be shared. (Received August 11, 2014)

1106-K5-213 **Sherrie Serros*** (serrossj@uwec.edu) and **Kathryn Ernie**, WI, and **Erick Hofacker** and **Barb Bennie**. *Rich Mathematical Tasks Aligned with Common Core Math Standards.*

Over the last two-plus years our Mathematics Science Partnership Grant "Math Transition into the Common Core Era" has focused on teachers meeting standards through the implementation of rich mathematical tasks. Once implemented, tasks focus not only on the content standards, but also on the practice standards.

We will share examples of rich mathematical tasks for both the middle school and high school levels. Tasks will focus on areas from: modeling, algebra, function, ratio & proportion, statistics, and probability. Some of these tasks have been created and modified by our participants, while others have come from leveraging existing Common Core resource databases that are available on the web. Lots of time has been spent discussing what constitutes too much scaffolding with students when implementing tasks like these in the classroom. While working on these tasks an emphasis is placed on having each individual or group share their different reasoning and representation. Full group discussion is used to provide an understanding of each person's thought process. Mini-whiteboards and technology are used to display their work. (Received August 11, 2014)

1106-K5-543 **Victoria Kofman*** (drkofman@comcast.net), Vika School, 1067 Lake Cook Rd., Wheeling, IL 60090. *Teacher Training: Helping the Students in Solving Word Problems.*

Most of the students come to our learning center unable to solve their required school-level math problems. In 2011, a general method of teaching students how to solve word problems was developed and piloted at Vika School. After several years, it became evident that the method was effective independent of teacher experience or student aptitude.

The method is based on subdividing one-step problems into 4 *logically homogeneous* categories: *part-part total, comparison, time problems*, and *proportion-type* problems. The students are taught to create pictorial representations, parameters, and equations specific to each category.

Only after students become proficient with representing and solving multistep problems of each type, *logically nonhomogeneous* problems are introduced. As a rule, problems on this level can not be standardized and require lateral thinking. However, students trained with *homogeneous logic* word problems first are able to solve these challenging problems.

Presently, all Vika School teachers learn the method and use it successfully, bringing students to the level of proficiency with word problems. Samples of student work demonstrate that the method works for all teachers who have completed the Vika School training program. (Received September 02, 2014)

1106-K5-1263 **AbdelNaser Al-Hasan*** (naser.alhasan@newberry.edu). *Writing a Specialized Professional Association (SPA) Report.* Preliminary report.

Ensuring an adequate supply of well-prepared and highly effective STEM teachers continues to be one of the central challenges to the United States in building a strong, synchronized STEM education system. According to NCTM: The CAEP accreditation process for mathematics teacher preparation programs requires a review of individual institutional programs by NCTM, the specialized professional association (SPA). The review process requires colleges and universities submitting program reviews to use the NCTM CAEP Standards as the basis for determining which of the required assessments provide evidence of candidate mastery of SPA-specific standards. In this talk, I will focus on several challenges a small institution such as Newberry College faces in order to have their mathematics teacher preparation program be nationally recognized. (Received September 11, 2014)

1106-K5-1289 **Diana White*** (diana.white@ucdenver.edu). *Revising the Mathematics Major to Align with the Common Core State Standards - Decisions and Challenges.*

Catalyzed by an NSF Noyce Scholarship Grant, the author's department revised the mathematics education track of the mathematics major to align with both the Common Core State Standards and the Conference Board of the Mathematical Sciences recommendations in their Mathematical Education of Teachers' documents. New courses were developed, existing courses revised, and the specific courses required were changed considerably. In this talk, we provide a brief overview of the changes, followed by a more in-depth look at the challenges faced in effectively implementing the program. (Received September 11, 2014)

1106-K5-1571 **Kevin Murphy*** (kevin.murphy@snc.edu). *Modeling and the Common Core – A Series of Workshops.*

In Fall 2012 and Spring 2013, there was a two part workshop held at UW-La Crosse for local High School mathematics teachers. The first workshop centered on modeling in the classroom through a task-driven event with concrete examples provided to see modeling first hand. Teachers were strongly encouraged to give at least one modeling task in their classroom and provide sample student work to discuss at the second workshop. This talk will give an overview of the proceedings of these workshops and summarize some of the findings. (Received September 14, 2014)

1106-K5-1976 **Dave Kennedy*** (dikenn@ship.edu), **Yvonne Lai** and **Judith Jacobs**. *Using Rich Mathematical Tasks to Promote the Standards for Mathematical Practice.*

In the era of the Common Core State Standards, our teacher certification programs need to prepare preservice mathematics teachers, both elementary and secondary, who understand the Standards for Mathematical Practice (SMPs) and can incorporate them in their teaching. We, as their teachers, need to become fluent in recognizing when opportunities for particular Practices come up. We will present a free, online resource we created to help mathematics instructors of preservice teachers bring the SMPs to life. (Received September 15, 2014)

1106-K5-2041 **Michael Von Korff*** (michael.vonkorff@reasoningmind.org) and **Victor Kostyuk**. *If we can't teach to the test, then we'll have to actually teach math.*

The new Common Core assessments represent a remarkable attempt to create tests that cannot be "taught to." The assessments are designed to require students to solve challenging problems, and so we must consider: how does one systematically teach problem-solving? In this talk, we outline Reasoning Mind's work to develop a problem-solving curriculum that will prepare students for the Smarter Balanced Common Core assessments. (Received September 15, 2014)

1106-K5-2094 **Patti Frazer Lock*** (plock@stlawu.edu), Dept of Math, CS, and Stats, St. Lawrence University, Canton, NY 13617. *Statistics and the Common Core.* Preliminary report.

The Common Core State Standards in Mathematics include an increased emphasis on statistics, with a particular focus on using simulation methods to develop understanding of statistical inference. We discuss the impact of these recommendations on undergraduate statistics instruction, on pre-service teacher training in statistics, and on proposed in-service teacher training in statistics. (Received September 15, 2014)

1106-K5-2139 **Catherine Case*** (ccase@ufl.edu) and **Anna Bargagliotti**. *Statistical Education of Teachers in the Common Core Era.*

The Common Core State Standards for Mathematics place heavy emphasis on statistics and probability, particularly in grades 6-12. However, effective implementation of the new rigorous standards depends to a large extent on the teachers who will bring them to the classroom. To address the preparation of those teachers, the American Statistical Association has commissioned the Statistical Education of Teachers (SET) report, which calls for collaboration between mathematicians, statisticians, teacher educators, and policy-makers to prepare teachers to teach the intellectually demanding statistics in the K-12 curriculum. This session will provide an overview of the recommendations put forth in the SET report. Specifically, this session will outline recommendations for the statistical preparation of pre-service and in-service teachers at all grade levels, highlighting the statistical problem-solving process and the distinctions between statistics and mathematics that have implications for teaching and learning. The session will also address pedagogical issues of particular relevance to statistics, such as the use of technology and the role of assessment. (Received September 15, 2014)

1106-K5-2254 **Jennifer Bergner*** (jabergner@salisbury.edu) and **Michael Bardzell** (mjbardzell@salisbury.edu). *A Partnership with Local Schools: Implementing the Paradigm Shift to Teaching Common Core Mathematics.* Preliminary report.

The Salisbury University (SU) Mathematics Department has partnered with local county schools over the past three years to provide two different types of professional development to help teachers (grades 3-12) make the paradigm shift to the Common Core State Standards for Mathematics (CCSSM). SU mathematics and mathematics education faculty created and delivered content modules that focused on aspects of content and pedagogy identified by mathematics coaches as being problematic for the teachers as they switched to the CCSSM. After each module, teachers created inquiry based learning tasks to be implemented in their classrooms and provided student work samples for future analysis. The second professional development opportunity involved university faculty meeting with groups of 8-10 teachers to collaboratively create inquiry based tasks for classroom use. Teachers saw these tasks to be relevant to their practice because they were created specifically for their students. In this presentation we will share struggles, successes, and future plans with respect to our partnership with the local schools and the transition to CCSSM. (Received September 16, 2014)

1106-K5-2370 **Karrolyne Fogel*** (kfogel@callutheran.edu) and **Nathan Carlson**. *Pre-service teachers views of the Standards of Mathematical Practice vs. the Content Standards.* Preliminary report.

CLU requires undergraduate pre-service elementary teachers to take a course on the underlying concepts of arithmetic. Beginning in Spring 2011, shortly after California adopted the Mathematics Common Core State Standards, students in this course were assigned short answer essay questions regarding the differences between the Standards of Mathematical Practice and the Math Content Standards. We analyze data from these student responses over the past four years to determine common student interpretations and misinterpretations of the Standards of Mathematical Practice. Additionally, we summarize their responses when asked which Standard of Mathematical Practice they were most surprised to find on the list. (Received September 16, 2014)

1106-K5-2435 **Adam Molnar*** (molnar@uga.edu). *Needs of High School Mathematics Teachers to Teach Conditional Probability.* Preliminary report.

Conditional probability appears in the US Common Core state standards, but did not appear in many earlier curricula. Anecdotal evidence suggested teachers had gaps in preparation. To investigate, I conducted task-based interviews with 25 current high school math teachers. Though not randomly selected, participants came from three states (GA, PA, SC) and had a representative range of experience, from an AP Statistics grader to many teachers with no prior probability teaching.

In the interviews, teachers answered content questions, discussed student misconceptions, and described what they felt they needed to teach probability topics. I will present results from the interviews. These include areas for content support, expressed desires of the participants, and requests for classroom-ready activities. (Received September 16, 2014)

1106-K5-2614 **John C Mayer*** (jcmayer@uab.edu). *Aligning Pre-Service Secondary Mathematics Curriculum at UAB with CCSS and MET-II.* Preliminary report.

Motivated by the recommendations of MET II, and by the CCSS Standards for Mathematical Practice, the Mathematics Department at UAB is in the process of revising its mathematics curriculum in order to permit prospective high school teachers to experience in their courses the process and content standards embodied in CCSS-M. Since our program is too small to offer courses in the mathematics major expressly for prospective teachers, we are on course to adopt the path of modifying certain existing courses to serve multiple purposes. The courses being modified, and the non-strict sequence in which they should be taken, are: Geometry, Modeling, Modern Algebra, Advanced Calculus I-II, and Research Methods (new). We have long taught Advanced Calculus as an inquiry-based course and Modeling as a project-based course. The changes will make the other three courses inquiry-based as well and align the curriculum, particularly in Geometry and Modern Algebra, more with "school mathematics from an advanced viewpoint." Since UAB has just become a UTeach replicate site (UABTeach), partnering with the three largest local school districts, we will be studying in some detail the impact of these changes on pre-service teachers and their teaching over the next five years. (Received September 16, 2014)

1106-K5-2721 **Gregory D. Foley*** (foleyg@ohio.edu), Ohio University, Athens, OH 45701-2979. *Advanced Teacher Capacity in Common Core Mathematics.*

The Advanced Teacher Capacity (ATC) project develops technological, pedagogical, and content knowledge among teachers in Grades 9-12 via two yearlong courses: Quantifying Uncertainty and Analyzing Numerical Trends (QUANT) and Modeling and Spatial Reasoning (Modspar). QUANT focuses on statistics and probability; selecting and enacting cognitively demanding instructional tasks; and using data collection devices, spreadsheets, and interactive statistical software. Modspar addresses discrete dynamical systems, modeling with continuous functions, and modeling with geometry; creating and implementing cognitively demanding student assessments; and using graphing and geometry applications, including three-dimensional interactive geometry software. This session will describe these courses and their relationship to the Common Core State Standards for Mathematics and will present the results of the related research since 2007. The session will explain how the standards for mathematical practice are integrated into QUANT and Modspar and how these courses could be adapted to preservice teacher preparation. (Received September 16, 2014)

Research on the Teaching and Learning of Undergraduate Mathematics

1106-L1-219 **Elise Lockwood*** (elise314@gmail.com), **Craig A. Swinyard** (swinyard@up.edu) and **John S. Caughman** (caughman@pdx.edu). *What's a factorial? Insights into student reasoning about the multiplication principle.*

Although combinatorial tasks are broadly accessible and provide opportunities for deep mathematical thinking, studies indicate that students have difficulty solving such tasks correctly. While research in this field is growing, more work is needed to examine ways of thinking about combinatorial concepts that might be helpful for students. In this talk we discuss an episode that arose during a ten-session teaching experiment in which two undergraduate students successfully reinvented four basic counting formulas. While their work supported them in solving 97%

of tasks correctly, our episode reveals surprising issues that arose in their ways of thinking about factorials and, more broadly, the multiplication principle. Specifically, the students did not display a robust understanding of the multiplication principle, and this appeared to constrain their fluency in reasoning about factorials. Our findings suggest that the repurposing of factorials – a concept many students first encounter in a calculus context – for use in a discrete setting could present a source of cognitive conflict for students. We explore several ways this could be further investigated in the context of the multiplication principle, and we also discuss implications for the reinvention methodology. (Received August 11, 2014)

1106-L1-273 **Samer S. Habre*** (shabre@lau.edu.lb). *Students' Challenges with Covariational Reasoning in the Polar Coordinate System.*

Covariational reasoning has been the focus of many studies but few looked into this reasoning in the Polar Coordinate System. Research on student's familiarity with polar coordinates and graphing in the Polar Coordinate System is scarce. This paper examines the covariational reasoning of students while plotting polar curves using the corresponding plot in the Cartesian plane. The study investigates not only the covariational reasoning associated with polar coordinates, but also explores how students synchronize the reasoning between the two coordinate systems. Results show that students' main challenge is associated with the negative radial distance. In addition, the study infers that the use of dynamical software for graphing purposes may have contributed to rather good results in mental actions related to covariational reasoning. (Received August 18, 2014)

1106-L1-428 **Kyeong Hah Roh** (khroh@asu.edu), School of Mathematical & Statistical Sciences, Arizona State University, PO Box 871804, Tempe, AZ 85287, **Austin Tanner*** (austin.tanner@asu.edu), 3510 E Hampton Ave #26, Mesa, AZ 85204, and **Yong Hah Lee** (yonghah@ewha.ac.kr), Department of Mathematics Education, Ewha Womans University, Seoul, 120-750, South Korea. *Undergraduate students' understanding of logical components in problem solving.*

Reasoning and proof are foundational aspects of mathematics, and logic is the basis in making valid arguments and proofs. Unfortunately, mathematics education research indicates that students and teachers do not always share mutual understanding of the meaning of logical components. The purpose of this presentation is to provide issues related to student understanding of logical components that arise when solving word problems in introductory proof courses. Thirty-six undergraduates voluntarily participated in this study. Among them we administered a survey to 31 students who had not taken any proof-oriented mathematics courses, and interviewed 5 others who had already taken an introductory proof course. Both survey and interview questions were based on a logical problem called the King and Prisoner Problem—a linguistically simple, yet logically challenging problem. In this presentation, we describe various invalid student solutions to the problem and discuss the logical fallacy amongst the student solutions. In particular, it is thought-provoking that student's logical fallacy is based on a lack of precise understanding of some basic logical components. This emphasizes the necessity of additional teaching to form mutual understanding of the meaning of the logical components. (Received August 28, 2014)

1106-L1-446 **Joshua D. Chesler*** (josh.chesler@csulb.edu), 1250 Bellflower Blvd, Long Beach, CA 90840-1001. *Choosing a definition of function: Linguistic concerns that impact students.*

Textbook authors and instructors make choices in how they define the concept of function. This study examines the impact of definition choice on undergraduate and graduate student performance, all of whom were mathematics majors. Data are comprised of student work on tasks requiring the application of different textbook definitions of functions. Choice of definition mattered. Indeed, seemingly minor differences in the wording of definitions may affect students' abilities to use the definition and to build a robust concept image of function. By drawing on ideas about action/process vs. object conceptions of function, it is hypothesized that certain linguistic features of definitions may impact a student's ability to use a definition of function and to develop a robust concept image. (Received August 28, 2014)

1106-L1-470 **Shiv Karunakaran*** (shivk@math.wsu.edu). *Examining expert and novice proving process for "linearity" of deductive logic.*

The argument for the importance of proving and of proof in the teaching and learning of mathematics has been repeatedly made by mathematics education researchers and by policy documents. There is also considerable research examining the existence of a gap in the proving and proof-constructing abilities of "novices" and "experts" in mathematics. Mathematicians have long claimed that the proving process cannot be considered to be a "linear" process and that undergraduates may view the proving process to be necessarily "linear". However, there is little to no empirical research that supports this familiar claim. This study uses grounded theory methods to examine "expert" and "novice" mathematicians in the process of proving mathematical statements. The finding reported in this session supports the claim that expert provers of mathematics are willing to knowingly and temporarily interrupt the deductive logic during their process of proving mathematical statements, in order to make progress towards constructing a complete deductive argument. However, novice provers may not demonstrate the same flexibility. (Received August 29, 2014)

1106-L1-509 **Stacy Marie Musgrave*** (stacy.musgrave@asu.edu). *Calculus Students' Meanings for Order of Operations and Consequences for Performing Differentiation Tasks.* Preliminary report.

Many Calculus students struggle to apply rules of differentiation and integration techniques. A possible source of this difficulty is weak structure sense; namely, students rarely attend to the structure of given functions or equations even though the structure dictates which rules to apply and the order in which to use them. For instance, recognizing the function $f(x) = 3x\cos(2-x)$ is a product of the two sub-expressions $3x$ and $\cos(2-x)$ is the first step in finding the derivative of f analytically.

Order of Operations determine the structure of expressions. For instance, Order of Operations establish the expression $3 - 5 \times 6$ is a difference in which the minuend is 3 and the subtrahend is 5×6. However, common treatment of Order of Operations in classroom settings supports students in developing meanings for Order of Operations limited to computation rather than as a means to parse structure.

In this talk, I discuss data collected from several tests and interviews conducted during a semester of introductory Calculus. I describe students' meanings for Order of Operations as a means to parse structure of expressions and discuss possible consequences for those meanings, particularly as they relate to performing differentiation tasks in Calculus I. (Received August 31, 2014)

1106-L1-624 **Eyob S Demeke** and **May Chaar*** (mej29@wildcats.unh.edu), Kingsbury Hall, 33 Academic Way, Durham, NH 03824. *The Role of Proof in Undergraduate Mathematics: A Case Study of Lagrange's Theorem.* Preliminary report.

In typical undergraduate advanced mathematics courses, professors spend ample class time presenting proofs; however little is know with regards to what students actually gain from these experiences. In our preliminary report we attempt to address this gap, specifically with respect to a proof of Lagrange's theorem. We used Mejia-Ramos and colleagues' (2012) model in designing a proof comprehension test and task-based interviews to shed light on (1) the extent to which undergraduates comprehend the proof and (2) what undergraduates gain or learn from reading the proof. Initial examination of our data reveals that although the participants could follow the proof line by line, they had difficulty identifying key ideas and summarizing the proof. Participants acknowledged their responsibility to fill in gaps in proofs; yet they had trouble justifying non-trivial assertions. Despite participants' superficial comprehension of the proof, we still observed that participants gained conviction and learned new definitions. (Received September 03, 2014)

1106-L1-655 **Aviva Halani*** (aviva.halani@gmail.com), 20 Main Street, Exeter, NH 03833. *Student Use of Venn Diagrams to Represent Additive and Multiplicative Reasoning in Counting Problems.*

This case study explored how a student could use Venn diagrams to explain his reasoning while solving counting problems. Open coding was used to identify the representations he used and the ways of thinking in which he engaged were analyzed using an existing framework. Venn diagrams were first introduced to the student as part of an alternate solution written by a supposed prior student. Following this introduction, the student in this study often chose to use Venn diagrams to explain his reasoning, stating that he was envisioning them. They were a powerful model for him – they helped him visualize the sets of elements he was counting and to recognize over counting. Further, he adopted the representation of the universal set in his diagrams when posing new questions and finding additive relationships between the solutions of the new and original questions. He transferred this representation to find multiplicative relationships in other problem posing situations. (Received September 04, 2014)

1106-L1-729 **Dov Zazkis*** (zazkis@gmail.com) and **Matthew Villanueva**. *Can mathematics majors make connections between informal arguments and formal proofs?*

A common recommendation in the proof education literature is that students should construct proofs by first constructing an informal argument for why a result holds and then attempting to formalize this argument. However, this type of proof generation strategy is rare among mathematics majors as highlighted by a recent large n study (Zazkis, Weber, & Mejia-Ramos, 2014). The study at hand explores hypothesized reasons for this rarity by testing what causes "distance" between informal arguments and formal proofs. In order to explore these hypotheses mathematics majors were presented with triplets consisting of one informal argument and two correct complete proofs, only one of which was based on the informal argument. This interview data was able to provide evidence for the relative importance of "content distance" when compared to "structural distance" (Pedemonte, 2007). Additionally, the relationships between students' approaches to reading proofs and their informal-to-formal connection making provide further insights into the informal-to-formal translation process. These highlight that students' perspectives on proof play a large role in determining whether they make normatively correct informal to formal connections. (Received September 05, 2014)

1106-L1-901 **Sarah Hanusch*** (sh1609@txstate.edu), Department of Mathematics, Texas State University, 601 University Drive, San Marcos, TX 78666. *The use of examples in the learning and teaching of proof writing.*

This study investigates the ways that undergraduate students use examples in their transition to proof course, and the influence that the instructor had on the students' decisions to use examples. Qualitative data was collected from the instructor and a sample of students via observations and interviews to investigate the connections between the teaching and learning of examples in this proof writing course, and then analyzed using the constant comparative method. The results show that the students can often state the circumstances in which an example could provide insight during proof writing, but struggle to during the implementation of the strategies. (Received September 08, 2014)

1106-L1-1348 **Jim Brandt*** (brandt@suu.edu), 351 W University Blvd, Cedar City, UT 84720, and **Jana Lunt** (janalunt@suu.edu) and **Gretchen Rimmasch Meilstrup** (rimmaschg@suu.edu). *Mathematicians' and Mathematics Educators' Perspectives on "Doing Mathematics".*

Educators often argue that mathematics should be taught so that the students in the course are actually "doing mathematics." Is there a consensus among mathematicians and mathematics educators as to the meaning of "doing mathematics"? In an effort to answer this question, we administered a survey to hundreds of university level mathematics and mathematics education faculty members. Participants ranked the importance of various mathematical activities and also responded to several open ended questions. Responses to the open ended questions were analyzed qualitatively to identify patterns. In this presentation, we will discuss the patterns we observed in analyzing the survey data, with a particular focus on the similarities and differences between mathematicians and mathematics educators. (Received September 12, 2014)

1106-L1-1363 **Ashley L Suominen*** (suominen@uga.edu). *Connecting Abstract Algebra to Secondary School Mathematics: How Mathematicians and Mathematics Educators Discuss Mathematical Connections.*

Many stakeholders concur that secondary teacher preparation programs should include study of abstract algebraic structures, and most certification programs require an abstract algebra course for prospective mathematics teachers. However, research has shown that undergraduate students struggle to understand fundamental concepts and, upon completion of the course, were unable to articulate connections between abstract algebra and secondary school mathematics. This two-part study involved a textbook analysis and a series of expert interviews. In the textbook analysis, I identified potential connections, categorizing them according to four types: alternate or equivalent representations, comparison through common features, generalization, and hierarchical or inclusion. I then interviewed 12 mathematicians and mathematics educators involved in abstract algebra research to understand how they describe connections between abstract algebra and secondary mathematics. Participants' descriptions of connections reflected their experiences with the secondary curriculum and differed according to their individual conceptualizations of abstract algebra. That is, participants with views of abstract algebra based on axioms, solving equations, or geometry prioritized different sets of connections. (Received September 12, 2014)

1106-L1-1430 **Tevian Dray*** (tevian@math.oregonstate.edu), Dept. of Mathematics, Oregon State University, **Corinne A. Manogue** (corinne@physics.oregonstate.edu), Dept. of Physics, Oregon State University, **David Roundy** (roundyd@physics.oregonstate.edu), Dept. of Physics, Oregon State University, **Joseph F. Wagner** (wagner@xavier.edu), Dept. of Mathematics and Computer Science, Xavier University, and **Eric Weber** (eric.weber@oregonstate.edu), College of Education, Oregon State University. *An Extended Theoretical Framework for the Concept of the Derivative.* Preliminary report.

This paper extends the theoretical framework for exploring student understanding of the concept of the derivative, which was developed by Zandieh. We expand upon the concept of a physical representation for the derivative by extending Zandieh's map of the territory to provide higher resolution in regions that are of interest to those operating in a physical context. We also introduce the idea of "thick" derivatives, which are ratios of *small* but not *infinitesimal* changes, which are practically equivalent to the true derivative. (Received September 13, 2014)

1106-L1-1444 **Daniel Visscher*** (davissch@umich.edu) and **Nina White**. *Comparing oral and traditional assessment in a content course for pre-service elementary school teachers.* Preliminary report.

A recent study on oral assessments summarizes several advantages to giving oral assessments, including that they: (1) develop communication skills, (2) are a more authentic assessment, (3) are more inclusive of different learning style and needs, and (4) are better at gauging understanding (Huxham, Campbell, Westwood, 2012). In this preliminary report, we will share results from a study on including oral assessments in a course for pre-service elementary school teachers (N=44). Using the anticipated advantages above as a framework, we describe how the assessment method affected the student experience and how and why it affected the instructor's summative assessment. We will also dedicate some time to discussing the instructor's experience in using this assessment method for first time. (Received September 13, 2014)

1106-L1-1622 **Guadalupe I Lozano*** (guada@math.arizona.edu). *The impact of instructional practices on conceptual calculus learning: what can analyzing item-bias tell us?* Preliminary report.

The Calculus Concept Inventory (CCI) is a fairly well-know instrument used to measure undergraduates' conceptual knowledge of calculus at universities in the US and abroad. Since its creation, a number of studies have sought evidence that interactive-engaged (IE) classroom practices, that is, particular flipped-classroom practices believed to foster the conceptual knowledge the CCI measures, are indeed positively associated with larger knowledge gains in the CCI. Yet, measuring instructional practices and quantifying their potential association with conceptual knowledge, are difficult tasks. For example, methods for assessing instructional practices (such as self-reporting or dichotomous binning) are often unreliable and/or inaccurate. My work aims to indirectly assess the impact of IE instruction on conceptual calculus learning by analyzing item-bias. The question explored is whether or not CCI-items appear to function differentially in (are biased in favor of) undergraduate populations uniformly taught using IE methods versus parallel non-IE undergraduate groups. Preliminary results comparing CCI performance of two large cohorts of US undergraduates (using Item-Response Theory based Differential Item Functioning) will be presented and discussed. (Received September 14, 2014)

1106-L1-1855 **Michelle Zandieh*** (zandieh@asu.edu), **Megan Wawro** and **David Plaxco**. *Inquiry-Oriented Linear Algebra (IOLA): An RME-based instructional sequence for change of basis and eigentheory.*

We take a design research approach to developing an innovative instructional sequence that supports students' reinvention of change of basis and eigentheory in linear algebra. Initial versions of the sequence were used in classroom teaching experiments in 2009-2010, during which we collected written and video data of small group and whole class discussions. The sequence is based on the Realistic Mathematics Education heuristic of guided reinvention that facilitates student engagement in mathematical activity from which instructors can guide them to the reinvention of mathematical ideas. The task sequence builds from students' experiences with linear transformations in $\mathbb{R}^2$ to introduce them to the idea of stretch factors and stretch directions and how these create a non-standard coordinate system. Students also build from these experiences to develop geometric and algebraic understandings of eigenvalues and eigenvectors, and to reinvent the diagonalization equation $PDP^{-1}x = Ax$. Our project website contains instructor resources such as examples of student thinking and implementation notes for this task sequence. (Received September 15, 2014)

1106-L1-1969 **Wes Maciejewski*** (wes@math.ubc.ca), 1984 Mathematics Road, Vancouver, BC V6T1Z2, Canada, and **Jon R Star** (jon_star@gse.harvard.edu), Gutman Library 442, 6 Appian Way, Cambridge, MA 02138. *Developing Flexible Derivative Procedures.* Preliminary report.

Procedures form an integral component of most introductory calculus courses. How students develop flexibility in executing these procedures is an under-explored topic. This presentation will report the results of a control-group trial, currently underway, of an intervention intended to improve students' flexibility with derivative-finding procedures. In the study, all students first complete a quiz on finding derivatives for product and rational functions. Students in the intervention section will then complete a worksheet of product and quotient derivative problems. Each question statement asks the students to solve the problem using one method, then again with another. Students are then prompted to evaluate which solution method is "better" and to justify this choice. The non-intervention students complete a similar assignment but are not required to re-solve problems using different methods nor are they prompted to reflect on their solution. All students will then be presented product and rational derivative problems on their midterm exams. We expect to find intervention students attempting variations on the canonical procedures typically used on these problems. (Received September 15, 2014)

1106-L1-2000 **Harrison E. Stalvey*** (hstalvey1@gsu.edu) and **Draga Vidakovic** (dvidakovic@gsu.edu). *Students' Reasoning When Sketching Graphs of Plane Curves Defined Parametrically.*

This report is on a portion of an investigation of fifteen second-semester calculus students' understanding of the concept of parametric function. While a substantial amount of research exists on students' general understanding of the concept of function, very little is known about how students reason about parametric functions. Here, our focus will be on how students reason when sketching graphs of plane curves defined parametrically. Employing APOS theory as our theoretical perspective, we will present examples that illustrate students' action and process levels of understanding of parametric functions when sketching the graph of a particular curve. We will conclude with implications for teaching and propose possible avenues for future research on the topic of sketching graphs of curves defined parametrically. (Received September 15, 2014)

1106-L1-2105 **Kedar M Nepal*** (nepal_k@mercer.edu), 1400 Coleman Avenue, Macon, GA 31207. *Perspectives of Beginning Mathematics Graduate Teaching Assistants on Teaching and Learning Mathematics and their Preparation Program.*

This qualitative study is an investigation of the teaching philosophies of beginning mathematics graduate teaching assistants (MGTAs). The study focused on the beginning and changing teaching philosophies of four purposefully selected MGTAs over a pre-service semester-long teaching assistant preparation program, and the subsequent in-service teaching experience phase. Three teaching philosophy statements (TPSs) from each participant were collected at three different stages of a semester-long teaching assistant preparation program (pre-service phase). Three one-on-one interviews were conducted with each of them in the following four semesters (in-service phase) after the conclusion of the pre-service preparation program course. These TPSs and transcribed interviews were analyzed using the constant comparative method. The participants expressed varying opinions about teaching and learning mathematics and the impact their preparation program had on them. Also, their perspectives changed differently over time during both the pre-service and the in-service phases. The participants expressed that the pre-service preparation program contributed mostly to alleviating their anxiety rather than changing their perspectives on teaching mathematics and teaching practices. (Received September 15, 2014)

1106-L1-2222 **Jennifer L Travis*** (jennifer.travis@lonestar.edu). *A self-regulated learning intervention for developmental mathematics students at a community college: Effects of study journals on achievement and study habits.*

This mixed methods study evaluated a study-journaling intervention for developmental mathematics students at a community college. Two weekly study journal worksheets were designed, based on key elements of self-regulated learning theory: forethought, self-monitoring, and reflection. In each of nine pairs of intact classes, one class was randomly assigned to the treatment (study journal) condition and the other to control. Propensity score matching was used to trim the groups so they had similar distributions of starting characteristics. Logistic regression was then used to estimate the intervention's effect on course success and final exam success. Departing students were counted among the unsuccessful. Due to implementation shortcomings, the original sample (n=257) was replaced by a modified sample (n=137). Propensity score matching trimmed the sample further (n=108). Treatment students were significantly more likely to leave the class than control students (odds ratio 2.94). However, qualitative data from focus groups and surveys indicated the study journals may have positively affected study habits. Together, qualitative and quantitative results suggest the intervention increased students' awareness of study habit inadequacies and time constraints. (Received September 16, 2014)

1106-L1-2354 **John Paul Cook*** (jpcook@usao.edu), **Brian Katz** and **Milos Savic**. *The Transfer of Knowledge from Groups to Rings: An Exploratory Study.* Preliminary report.

Typical undergraduate course sequences in abstract algebra initiate with group theory before proceeding to ring theory. This sequencing, along with the structural similarities between groups and rings, enables many ring-theoretic concepts to be formulated in terms of results from group theory. What remains to be seen, however, is the extent to which students are able to transfer their knowledge of groups while studying topics in ring theory. Using Wagner's transfer in pieces framework, we conducted an exploratory study to investigate how students in an inquiry-oriented classroom capitalized on their knowledge of groups to make sense of rings. Preliminary results indicate both instances of obvious transfer (e.g. subgroup to subring) and also more creative approaches that might lend insight into how students think about ring structure (e.g. characterizing field-like structures as 'abelian grouprings'). (Received September 16, 2014)

1106-L1-2440 **Karen Keene***, PO Box 7801, North Carolina State University, Raleigh, NC 27603, and **Nicholas Fortune** and **Celethia McNeil**. *We will present the results of a qualitative analysis of the amount and quantity of students' discourse in an inquiry oriented differential equations class and those students academic performance.* Preliminary report.

There is interest in connecting students' participation in student-centered classrooms and their performance on homework, projects, and formal assessments. In this report, we will present the results of a quantitative analysis of the amount and quantity of students' discourse in an inquiry oriented differential equations class and those students academic performance. (Received September 16, 2014)

1106-L1-2442 **Julie M. Skinner Sutton*** (jmsutton@uta.edu). *The Influence of Dynamic Visualizations in Calculus Learning.*

Student success in calculus is of paramount importance and crucial in response to the need to produce more STEM graduates in the United States. Since incorporating dynamic visualization into the calculus experience provides a strategy for possibly increasing student understanding of the concepts in calculus, we investigate the role of dynamic visualization in calculus learning at the university level. The concept images and concept definitions held by students often create conflict as students create appropriate schema within calculus. We examine findings relating to uncontrollable mental imagery with regard to student understanding of derivative as a rate of change by comparing student interviews and experiences when interacting with dynamic visualizations in contrast to engagement with static exercises. Our results are from a study of nine students; four identified as visualizers and five as non-visualizers. Each student was assigned to interact either with dynamic visualizations or to work static exercises during a series of four interviews. Comparisons reveal the emergence of cognitive conflict and its resolution for those students encountering the dynamic visualizations but this resolution is not evident for those only engaged in static work. (Received September 16, 2014)

1106-L1-2498 **Alison G. Lynch*** (gordon@math.wisc.edu), **Pooneh Sabouri** (psabouri@nyu.edu), **Rebecca Vinsonhaler** (vinsonhaler@wisc.edu) and **Amy B. Ellis** (aellis1@education.wisc.edu). *Undergraduates' Example-Related Activity in Proving Conjectures.* Preliminary report.

An overreliance on example-based reasoning has typically been viewed as a stumbling block for students when learning to prove. In this study, we investigate the mathematically productive ways in which undergraduates may use examples while proving conjectures. We interviewed ten undergraduates as they engaged in tasks requiring the proof or disproof of conjectures. In this preliminary report, we discuss three ways that the undergraduates used examples while trying to develop a proof: using examples to ascertain the correctness of an algebraic representation, using examples to try to illuminate the next step in a proof, and using examples to explain their reasoning for the general case. (Received September 16, 2014)

1106-L1-2570 **Andrew Hoffman*** (hoffma45@purdue.edu), 100 N University St, West Lafayette, IN 47907, and **Jia He** and **Leonardo Medel**. *Teacher as Learner: Reflections from Pre-service Mathematics Teachers.*

This session describes pre-service teachers' (PSTs') reflections on learning algebra at the end of their teacher education programs. Data comes from two focus group interviews at each of four purposefully chosen secondary mathematics teacher education programs and we report on emergent themes identified through qualitative analysis. For example, reasoning and proof were emphasized across universities, but PSTs reported that the practices played different roles at different universities. In some cases, proof was used as an assessment and PSTs were supposed to reproduce memorized proofs. In other cases, reasoning and proof were considered tools for learning, granting access to important mathematical truths. This dichotomy about reasoning and proof led us to consider university characteristics. Only two of the case study sites had mathematics educators involved in their mathematics departments. PSTs from these sites more often connected content from their mathematics courses to K-12 learning and commented about taking ownership of their mathematical knowledge. This session presents ideas about teaching mathematics to PSTs and fostering collaboration between mathematics educators and mathematicians. (Received September 16, 2014)

1106-L1-2633 **Hayley ML Milbourne***, 6475 Alvarado Rd, Suite 206, San Diego, CA 92120.
Implementing inquiry-oriented instructional materials: A comparison of two classrooms. Preliminary report.

Prior research in linear algebra education has focused on documenting and understanding the difficulties students have with specific topics. In more recent years, the research has started to shift towards developing instructional methods to address these issues. In this study, I explore the ways in which two instructors implement inquiry-oriented materials focused on span and linear (in)dependence. One of the instructors had prior experience with these materials and the other did not. Through an analysis of video recordings of these classes, I use the Inquiry-Oriented Discourse Moves framework to analyze how each instructor conducts whole-class discussion and the affordances these discussions provide their students. Initial results suggest large differences between the two teachers in the types of discourse moves used, leadings to differences in the affordances provided to the students. (Received September 16, 2014)

1106-L1-2683 **Hyejin Park*** (hjpark3@uga.edu), Athens, GA 30602. *Prospective teachers' evaluation of students' arguments that use mathematical induction.* Preliminary report.

Principles and Standards for School Mathematics note that "Students should learn that certain types of results are proved using the technique of mathematical induction"(NCTM, 2000, p. 345). Secondary mathematics teachers must teach MI, and therefore have solid knowledge of MI, including proficiency reading and analyzing student arguments that use MI. Most studies on the learning and teaching of MI (e.g., Harel, 2001) have focused on student and teacher knowledge of MI. Little research has examined how teachers read and reflect on student arguments. In this study, I examined the characteristics of three prospective secondary teachers when analyzing student arguments using MI, presented in an interview setting and situated in the context of teaching at the secondary level. In the examination of arguments, participants focused on the base and inductive steps proposed by the principle of MI. They checked the correctness of algebraic manipulations showing how P(n+1) was derived from P(n), but disregarded algebraic errors in their validations. When asked to give criteria for evaluating student arguments, participants wished to see correct base case, inductive step, and algebra. This raises questions about how participants will evaluate student arguments if algebraic errors are present. (Received September 16, 2014)

1106-L1-2685 **Mary Beisiegel***, 368 Kidder Hall, Department of Mathematics, Oregon State University, Corvallis, OR 97331. *From Telling and Doing to Thinking, Explaining, and Anticipating: Mathematics Graduate Students' Changing Descriptions of Their Role as Instructors.*

The goal of this study was to determine how mathematics graduate teaching assistants' (MGTAs) perspectives of teaching changed as a result of exposure to professional development (PD) for a course that had new expectations of how they engaged with undergraduate learners. Specifically, MGTAs were paired with instructors for a redesigned College Algebra course, where at least half of classroom time was structured around student engagement in mathematical tasks, rather than on lecture. Expectations for the MGTAs included facilitation student groups' engagement in mathematical tasks not by lecturing, but instead by question posing and not directly answering students' questions. PD support was offered for two full days at the beginning of the term and weekly two-hour meetings. During the ten-week term, five MGTAs were interviewed four times and asked questions about their perspectives of quality mathematics teaching and learning, the roles of instructors and students, and what a well taught mathematics lesson looks like. Interviews were analyzed with thematic analysis. Results that will be presented are the MGTAs' changing descriptions of mathematics teaching, how they describe a well-taught mathematics lesson, and the implications for how they view their own teaching practices. (Received September 16, 2014)

1106-L1-2876 **Sepideh Stewart*** (sstewart@math.ou.edu), **Clarissa Thompson** and **Noel Brady**.
From intuition to the formal world of mathematical thinking: A geometric topologist's teaching diaries and thought processes. Preliminary report.

Developing an intuition for abstract mathematical concepts is a skill that takes considerable experience and practice. Definitions, theorems, and proofs are essential to mathematical representations, yet many mathematicians also rely on visualizing and maintaining key examples in mind. We investigated a mathematics professor's thought processes as he taught Algebraic Topology. His teaching diaries were discussed in weekly meetings with a mathematics educator and a cognitive psychologist. We examined his worked examples and the physical prompts used to evoke students' intuitions and formal mathematical thinking. He debated whether in-depth coverage used to promote visualization of concepts would come at the expense of a lack of breadth. Furthermore, we analyzed his ability to navigate the embodied, symbolic, and formal mathematics worlds as he encouraged students to push their algebraic insights and connect them to topology. Our data also included student interviews and daily journals, a questionnaire, and end-of-semester course evaluations. This research is part of an interdisciplinary study examining mathematicians, physicists, and engineers' visualization abilities. We will develop a model of expert visual thinking that may improve students' spatial representations. (Received September 16, 2014)

1106-L1-2901 **Roger Mark Fischer** (rogerfischer@suu.edu), 537 West 2075 North, Cedar City, UT 84721, and **Brian J Lindaman*** (blindaman@csuchico.edu), California State University Chico, Mathematics and Statistics Department, Holt 206, Chico, CA 95929. *Rational Numbers and the Common Core State Standards: A Descriptive Case Study.*

Previous K-12 mathematics standards have regarded facility with various representations of rational numbers as sufficient for understanding. The Common Core State Standards for Mathematics (CCSSM), however, emphasize a more general understanding of rational numbers while also targeting repeating decimal representations. Existing literature suggests that teachers' content knowledge is inadequate to meet this goal.

The purpose of this study was to describe understandings held by a sample of middle grades teachers and how these understandings manifested during instruction. An open-ended interview protocol was used to collect information, and observations of classroom instruction provided additional data. Data were analyzed both between and within cases using responses from the interview as a basis for comparison.

Results found teachers' understanding of rational numbers varied considerably with context. Each observed teacher also displayed at least one understanding that manifested during the interview. Despite none of the teachers demonstrating the "unified understanding of number" called for in the CCSSM, several strategies for addressing these idiosyncratic understandings were developed, and have significant implications for undergraduate K-6 pre-service programs. (Received September 17, 2014)

Revitalizing Complex Analysis at the Undergraduate Level

1106-L5-167 **Lawrence J. Crone***, 463 Walters Hollow Road, Alum Bank, PA 15521. *Using Color Graphs in Complex Analysis.*

One difficulty in teaching (and learning) complex analysis is that it is hard to use graphs to observe the behavior of functions. In this talk I will describe a color graphing technique which I have been using for thirty years and a Visual Basic program which is now available for free download. Imagine a program which displays a fifth degree polynomial in a way that makes the (approximate) location of the zeroes obvious. See poles, branch cuts and essential singularities. At this point the program recognizes algebraic operations and exp (exponential), log (natural log), sin, cos, tan and atn (arctan) functions. (Received August 04, 2014)

1106-L5-352 **Hortensia Soto-Johnson*** (hortensia.soto@unco.edu), UNC School of Mathematical Sciences, Ross Hall 2240C, Greeley, CO 80639, and **Marki Dittman**. *Sprinkling Complex Analysis Across the Undergraduate Curriculum.*

There is concern that complex analysis has lost its prominence in undergraduate mathematics, science, and engineering. There is further uneasiness that secondary mathematics teachers, who are the first to introduce complex numbers to students, do not complete a course in complex analysis. The purpose of this presentation is to share how complex analysis was integrated into a second semester course of higher geometry for prospective secondary teachers. Specifically, we will share our activities designed to explore Möbius transformations and their geometric interpretations. We will discuss students' reactions to these activities. (Received August 24, 2014)

1106-L5-439 **William M Kinney*** (bkinney@bethel.edu), Bethel University, 3900 Bethel Drive, P.O. 95, St. Paul, MN 55112. *Flipping the Classroom and Mathematica-Based Modules in Complex Analysis.* Preliminary report.

I have a long-term goal to "flip" many of the mathematics courses I teach, meaning that content is delivered outside of class through videos, while in-class time is spent working on active-learning modules. The modules I construct have a special focus on using Mathematica to help students in important learning tasks: constructing simulations to explore, making and testing conjectures, and understanding topics more deeply. This presentation will illustrate some of these modules, some of which involve animating figures in Tristan Needham's book, *Visual Complex Analysis*. I will also invite interested people to join me in this work as a collaborative project to help revitalize the teaching of Complex Analysis at the undergraduate level. (Received August 28, 2014)

1106-L5-465 **William C Bauldry*** (`bauldrywc@appstate.edu`), Dept of Math Sciences, Appalachian State University, 121 Bodenheimer Dr, Boone, NC 28608. *Microworlds with Maple for Investigating Complex Analysis.* Preliminary report.

We show how Maple can be used to augment an introductory complex analysis course. Computations and plots are the easy first steps. More meaningful student investigations can be designed using Maple's components to generate 'microworlds' in which students can explore complex variables using the *Action-Consequence-Reflection* (ACR) paradigm. (Received August 29, 2014)

1106-L5-709 **Stephan Ramon Garcia***, Department of Mathematics, Pomona College, 610 N. College Ave, Claremont, CA 91711. *Approaches to Cauchy's Theorem.*

We hope to initiate a discussion about various methods for introducing Cauchy's Theorem. Although Cauchy's Theorem is the fundamental theorem upon which complex analysis is based, there is no "standard approach." The appropriate choice depends upon the prerequisites for the course and the level of rigor intended. Common methods include homotopy theory, Green's Theorem, or Goursat's lemma, each of which has its positives and negatives. (Received September 05, 2014)

1106-L5-1210 **Beth Schaubroeck***, beth.schaubroeck@usafa.edu, and **Michael Brilleslyper**, mike.brilleslyper@usafa.edu. *Discovering the Gauss-Lucas Theorem.* Preliminary report.

The Gauss-Lucas Theorem states that the zeros of the derivative of a polynomial are contained within the convex hull of the zeros of the original polynomial. This result is not always apparent in the real domain. However, like many other results in analysis, extending to the complex domain resolves the apparent inconsistencies seen when restricting to the reals. This beautiful result has an elementary proof but is rarely mentioned in an undergraduate course. We present a possible path for introducing the topic. (Received September 11, 2014)

1106-L5-1350 **Eric Sullivan*** (`esullivan@carroll.edu`), 1601 N Benton Ave, Helena, MT 59625. *Unifying PDEs, Linear Algebra, and Complex Analysis.*

Complex analysis is an essential part of the undergraduate mathematics major, but many traditional curricula appear to be missing some of the modern applications to complex analysis. In this presentation we'll give an example curriculum that interlaces traditional complex analysis topics with applications including Fourier analysis, linear algebra, and partial differential equations. The goal of this sample curriculum is to create a course that is not only proof-intensive but also recaps some of the larger themes and applications from linear algebra and PDEs to give students a flavor of the applicability of the subject. We will conclude with an open discussion of the traditional topics that are omitted in order to make room for applications. (Received September 12, 2014)

1106-L5-1804 **Robert Sachs*** (`rsachs@gmu.edu`). *A new complex analysis / algebra / geometry transition to higher mathematics course in development.*

This report discusses the syllabus of a new, developing "transition to higher math" course. We outline the topics and sequencing, discuss the intended benefits of a successful implementation, and begin a wider discussion. The course links complex variables, algebra, and plane geometry. The central role of complex algebra and analysis in the 19th century development of many branches of mathematics makes the course a way to introduce several topics, and to pique interest and increase achievement in upper level math courses. The course both introduces and unifies complex variables, abstract algebra, and hyperbolic geometry. (Received September 15, 2014)

1106-L5-1925 **Paul Zorn*** (`zorn@stolaf.edu`). *Complex Curve Maps.*

The standard elementary functions of single-variable calculus are easily represented graphically as curves in the xy-plane. But the ease of plotting these functions has costs, including a too-rigid identification of functions with plane curves. These curves may also work poorly to illustrate subtler ideas, such as discontinuity, singularities, and, crucially, functions viewed as mappings.

In complex analysis the notion of function as mapping is crucial, both pedagogically and to the nature of complex functions themselves. Analytic functions really *are* mappings with important mapping properties, such as conformality and behavior near singularities.

There are many ways to use technology to visualize complex functions $w = f(z)$. The simple curve mapping tool I'll illustrate does what the name suggests: It shows colored images in the complex w-plane of simple colored spirals in the z-plane. (Color is used to indicate the angular coordinate of a given input.) Despite its simplicity, the tool can be used to illustrate various complex analytic phenomena, including conformality, preservation of orientation, and the behavior of functions that are differentiable or real-analytic, but not analytic in the complex sense. (Received September 15, 2014)

1106-L5-1990 **Tamas Forgacs*** (tforgacs@csufresno.edu), 5245 N. Backer Ave M/S PB108, Department of Mathematics, California State University, Fresno, Fresno, CA 93740-8001. *Implementing modules - a case study.* Preliminary report.

One of the approaches to revitalizing complex analysis at the undergraduate level is to deliver interesting and exciting modules on topics which allow students to see complex analysis in action, thereby motivating the systematic development of topics later in the course, or perhaps even later in a more advanced class. This talk will report on the implementation of two such modules at Fresno State in the fall of 2014, and hopes to contribute to the ongoing discussion on how best to move forward with some concrete evidence. (Received September 15, 2014)

1106-L5-2730 **Jeff Randell Knisley*** (knisleyj@etsu.edu). *Complex Differentiation in Contexts.*

Complex analysis is elegant to the point of being ethereal, but often students fail to see either. A major contributor to this phenomenon is that the definition of the derivative tends to be motivated by its analogy to real differentiation rather than by a geometric problem or a physics context.

Fortunately, there are numerous fields of science, technology, engineering, and mathematics that continue to benefit richly from ideas in complex analysis, and these can be used to not only motivate complex analysis but also to provide "real world" interpretations of complex derivatives. For example, conformal mapping can be enlivened by something as simple as the fact the square of an ellipse centered at the origin results in an ellipse with one focus at the origin. This simple example can also be as a context for complex differentiation of conformal maps.

Likewise, in this presentation we introduce applications of complex analysis in population genetics, in numerical analysis, in quantum mechanics, and in several other fields. The focus, however, is on providing contexts for interpreting complex derivatives geometrically and otherwise, much like a calculus sequence uses multiple applications of tangent lines and rates of change. (Received September 16, 2014)

1106-L5-2827 **Russell W. Howell*** (howell@westmont.edu), Department of Mathematics, Westmont College, Santa Barbara, CA 93108, and **Alan Noell** (noell@math.okstate.edu), Oklahoma State University, Department of Mathematics, Stillwater, OK 74074. *Revitalizing Complex Analysis: Three Philosophies (part 1).*

Complex analysis, despite its beauty and power, seems to have lost some of the prominence it once enjoyed in undergraduate mathematics, science, and engineering. With support from NSF a team of 16 people convened last summer for one week to investigate the possibility of revitalizing the subject. Three distinct approaches emerged. This session will give an overview of the approaches, look closely at the first, and conclude with an interactive discussion between some of the participants and members of the audience. (Received September 16, 2014)

1106-L5-2845 **Russell W. Howell*** (howell@westmont.edu), Department of Mathematics, Westmont College, Santa Barbara, CA 93108, and **Paul Zorn** (zorn@stolaf.edu), Department of Mathematics, St. Olaf College, Northfield, MN 55057. *Revitalizing Complex Analysis: The Next Steps.*

This session concludes with an overview of various approaches presented that offer some hope for revitalizing the subject of complex analysis at the undergraduate level. It will be largely interactive with panel members who will solicit input from members in the audience. The goal is to envision further action that may be taken in the hopes of improving the teaching of this important subject. (Received September 16, 2014)

1106-L5-2857 **Ricardo L. Diaz*** (ricardo.diaz@unco.edu). *The Bermuda Triangle and Geometric Visualization of Complex Path Integrals.* Preliminary report.

As a pedagogical tool for explaining the key properties of complex path integrals in an undergraduate course, we relate them to a problem in navigation. What happens if we attempt to reconstruct a ship's trajectory from knowledge of its instantaneous velocity vector, in a situation where the ship's compass and pendulum clock are affected by local magnetic and gravitational anomalies? The velocity vector computed using the unreliable instruments is a rotated, dilated copy of the true velocity vector. The relation between these two velocity vectors has the conformal form $dw/dt = f(z(t))(dz/dt)$, where $z(t)$ is the true path and $w(t)$ is the falsely reconstructed path. Here $f(z)$ is a local complex factor that represents the local rotation and time dilation. Indefinite integration of this relation produces a reconstructed curve $w(t) = \int_0^t f(z(s))(dz/ds)ds$ that can differ dramatically from the true path. Several major topics in complex analysis can be explored visually using this geometrical model, such as necessary and sufficient conditions for path independence of integrals, special cases of the Cauchy Integral formula, and the Argument Principle. (Received September 16, 2014)

1106-L5-2867 **Alan Noell*** (noell@math.okstate.edu), Department of Mathematics, Oklahoma State University, Stillwater, OK 74074, and **Russell W. Howell** (howell@westmont.edu), Department of Mathematics, Westmont College, Santa Barbara, CA 93108. *Revitalizing Complex Analysis: Three Philosophies (part 2).*

Assuming that the teaching of complex analysis is in need of revitalization, this session dovetails with the previous one by focusing on two approaches that grew out of a week-long NSF-sponsored workshop last summer. It will present recommendations, solicit interaction between some of the workshop participants and members of the audience, and set the stage for upcoming presentations. (Received September 16, 2014)

1106-L5-2905 **Jane M McDougall*** (jmcdougall@coloradocolelege.edu), Dept of Mathematics and Computer Science, Colorado College, 14 E. Cache La Poudre, Colorado Springs, CO 80903. *Elementary Geometry and Ptolemy's theorem in a complex analysis course.* Preliminary report.

With increased accessibility of applets and computer algebra systems in recent years, there have also been increased possibilities for students to visualize theory and applications of a more geometric nature in complex analysis. We examine some generalizations of Ptolemy's beautiful theorem from elementary geometry that might be incorporated in an elementary course in complex analysis. (Received September 17, 2014)

Scholarship of Teaching and Learning in Collegiate Mathematics

1106-M1-66 **Mike Pinter*** (mike.pinter@belmont.edu), Department of Mathematics and Computer Sci, Nashville, TN 37212. *Encouraging a "Growth Mindset" in Our Mathematics Courses.* Preliminary report.

In her book Mindset (2006), Carol Dweck contrasts a growth-oriented mindset with a fixed-oriented mindset and suggests that a growth mindset can be learned with time and practice. Doyle and Zakrajsek (2013) describe characteristics of the two mindsets when dealing with challenges, criticism and several other dimensions that can impact student behaviors. Our primary question for this presentation is how well do activities and strategies that encourage a growth mindset toward learning mathematics actually impact student learning. In this presentation I will briefly outline Dweck's mindset framework and consider ways to develop, encourage and support a growth mindset in our mathematics students' approach to learning. In this preliminary report of an ongoing investigation, I will briefly discuss assessments of the effectiveness of targeting strategies for a growth mindset using student work, participation and feedback as the primary evidence.

References Doyle, T., and Zakrajsek, T. (2013). The new science of learning: How to learn in harmony with your brain. Sterling, Virginia: Stylus. Dweck, C.S. (2006). Mindset: The new psychology of success. New York: Random House. (Received June 20, 2014)

1106-M1-262 **Richard A. Edwards*** (edwar491@msu.edu), 113 North Kedzie Hall, Michigan State University, East Lansing, MI 48824. *Believe it or Not! Challenging Prospective Teachers' Beliefs About Mathematics in a History of Mathematics Course.*

What do future elementary teachers believe about the nature of mathematics, and to what extent are such beliefs amenable to change? Prior research indicates that personal beliefs about mathematics strongly influence teachers' pedagogical decisions. This talk is a report on a research project that studied prospective elementary teacher beliefs both before and after a course in the history of mathematics. This study employed a four-dimensional framework developed particularly to assess mathematical beliefs. Participants were surveyed both at the start and at the end of the course on topics such as the relevance of mathematics in society, the need for math in everyday life, and the nature of mathematical thought. In addition, a subset of students participated in semi-structured interviews throughout the semester. Results indicate that some prospective elementary teachers initially viewed mathematics as valuable only for its practical uses, and thought of math as a set of rules and procedures. After a course in the history of mathematics, however, several participants reported remarkably different beliefs. This talk concludes with implications for teaching the history of mathematics, and for teacher education. (Received August 16, 2014)

1106-M1-277 **Matthew G Jones*** (mjones@csudh.edu). *The Effectiveness of Concept Questions in a Transition to Proof Course.* Preliminary report.

Concept questions are a core feature of Interactive Engagement, a pedagogical approach indicated by research as effective in physics (Hake, 1998), and more recently, in calculus (Epstein, 2013). Concept questions are designed as brief, typically non-computational questions in a true-false or multiple-choice format, in which the question is posed, all students are required to respond (via clickers or other devices), students discuss their thinking, and then students respond again. If the class has not converged on the correct answer, then the instructor engages the students in further explanation or activity on the concept. The fundamental question that will be explored is: What is the impact of using concept questions on students' understanding of core ideas in a transition to proof course? To evaluate this question, I will explore students' performance on concept questions and its relation to their performance on exams. In addition, I will compare students' performance on the final exam to performance of a prior cohort of students in the same course in which concept questions were not used extensively. In addition, I will describe how the questions are integrated into the course meetings and grading structure, and I will share sample questions. (Received August 18, 2014)

1106-M1-508 **Rebecca Anne Dibbs*** (`rebecca.dibbs@tamuc.edu`). *Attribution, participation, and formative assessment in introductory calculus: A growth model.* Preliminary report.

Prior formative assessment research has shown positive achievement gains when classes using formative assessment are compared to classes that do not. Prior research suggested that students that participated regularly in formative assessment had significantly greater achievement than those that did not. Furthermore, there were qualitative differences in patterns of positive learning behavior and beliefs about learning, attribution, between students completing formative assessment regularly from their classmates. However, prior studies have not had baseline attribution data available, so it was unclear what how attribution beliefs influenced student learning. The purpose of this study was to investigate influence of attribution on the achievement of the students in two introductory calculus using growth models. (Received September 07, 2014)

1106-M1-700 **Tara C Davis*** (`tdavis@hpu.edu`), 1164 Bishop, UB 210 A, Honolulu, HI 96183, and **Georgianna L Martin** (`gmartin@hpu.edu`), 45-045 Kamehameha Highway, HLC 311C, Honolulu, HI 96825. *Do students really know what a function is?* Preliminary report.

In order to assess the overall understanding of the concept of a function, we conducted an experiment with post-calculus math majors at our university. In an upper division problem solving course, the students were asked to present their understanding of a function in groups of 2 – 3. Specifically they were asked to create a presentation discussing functions, their characteristics, the role of the variable and typical misconceptions. The presentations were video recorded and then transcribed. Analyzing the transcripts, we will discuss our insights into student understanding of the function concept as well as some of the common learning difficulties that we have identified. (Received September 04, 2014)

1106-M1-900 **Sarah Hanusch*** (`sh1609@txstate.edu`), Department of Mathematics, Texas State University, 601 University Drive, San Marcos, TX 78666, and **Sonalee Bhattacharyya** (`sb1212@txstate.edu`). *Examining proficiency with operations on irrational numbers.*

Fluency with our number system is a critical part of mathematics. Understanding how rational and irrational numbers work and fit in to the number system as a whole is at the foundation of a good understanding of mathematics (Fischbein, Jahiam, & Cohen, 1995). In this study, we present developmental mathematics students with a task which tests understanding of the closure of irrational numbers under addition and multiplication. We analyze the data with the strands of proficiency framework from *Adding It Up* (Kilpatrick, Swafford, & Findell, 2001), searching for evidence of each strand. The results indicate that no individual strand is particularly strong or weak among all of the students, yet small example spaces of irrational numbers may be to blame for many errors from the students. We conclude with implications for the classroom. (Received September 08, 2014)

1106-M1-1052 **Jennifer Kosiak*** (`jkosiak@uwlax.edu`), **Robert Allen** (`rallen@uwlax.edu`), **Bob Hoar** and **Jim Sobota** (`jsobota@uwlax.edu`). *FastTrack: Enhancing College Readiness in Mathematics.*

The FastTrack Summer Math Program is a bridge program designed to enhance the mathematical skills of incoming freshman that have placed into a developmental mathematics course at the University of Wisconsin-La Crosse. FastTrack students participate in a 6-week online program prior to coming to campus for a one-week workshop. During the on-campus stay, students retake the University of Wisconsin System Mathematics Placement Exam. To address the research question, what is the impact of the FastTrack program on college readiness, this session will examine the results from this three-year project in relationship to pre-and post-placement data, grades in subsequent college level mathematics course work, and retention data. (Received September 10, 2014)

1106-M1-1053 **Bob Hoar*** (rhoar@uwlax.edu), **Jim Sobota** (jsobota@uwlax.edu) and **Jennifer Kosiak** (jkosiak@uwlax.edu). *Results from a College Readiness Math MOOC.*

The College Readiness Math MOOC (Massive Open Online Course) was designed to enhance students' mathematical skills in order to be successful in a college level mathematics course. The course is arranged into 10 modules covering topics that will enhance algebraic knowledge and skills in areas related to ratios and proportional relationships, geometry, and solving a variety of equations and inequalities. Using pre- and post-test data, item analysis, and user analytics, this session will focus on the following research questions: 1) What areas of college readiness were significantly enhanced by participation in the Math MOOC? and 2) What patterns in student activity enhanced performance in the Math MOOC? (Received September 10, 2014)

1106-M1-1079 **Shelly M McGee*** (smmcgee@ollusa.edu), 411 SW 24th St, San Antonio, TX 78207, and **Jess A White-Phillip** (jwhite-phillip@ollusa.edu), 411 SW 24th St, San Antonio, TX 78207. *Engaging students using temperament profiles: Using ROMP to increase student success in first and second year STEM courses.* Preliminary report.

Biology and mathematics professors collaborate to increase student engagement and conceptual understanding across STEM courses to increase student retention within the discipline. The faculty examined temperaments and learning/communication preferences as barriers to student success, and developed ROMP as a solution. ROMP is an acronym for the temperamental learning questions as used by each group: Relevance, Objective, Mechanism, and Pattern. Each "learning question" category of ROMP appeals to a different temperament and engages students according to their learning style. By consciously addressing these four preferences, the faculty attempted to increase student engagement, conceptual understanding of key scientific and mathematical topics, inform students about different learning styles, and empower them to develop personal learning strategies. Faculty also constructed lectures and class activities to divide class instructional time to engage each of the learning styles. This presentation will cover the background research into temperament and learning styles, differences in brain function between the types, and outline the initial implementation of ROMP in college algebra, pre-calculus, and other STEM courses, as well as lessons learned. Preliminary data will be presented. (Received September 10, 2014)

1106-M1-1344 **Jim Brandt** and **Jana Lunt***, janalunt@suu.edu, and **Gretchen Rimmasch Meilstrup**. *Emphasizing Mathematical Definitions in a College Algebra Course.* Preliminary report.

Definitions play a critical role in mathematics. Unfortunately, many undergraduate students do not recognize their importance. Compounding this, definitions and their roles may not be emphasized in lower division mathematics courses. Students' lack of understanding of mathematical definitions can lead to difficulties in current and future mathematics courses. In this project, we taught a college algebra course using a variety of activities designed to emphasize mathematical definitions. Further, we assessed the impact of these activities on students' abilities to work with novel definitions and solve standard computational problems. In this presentation, we will describe some of these classroom activities and discuss the results of our assessment. (Received September 12, 2014)

1106-M1-1378 **Elaine Rumsey Wagner*** (wagnere@byui.edu), **Susan Marla Orme** and **Heidi Jean Turner**. *Student Use of Example Generation in a Calculus Course: Implementation and Student Attitudes.*

Mathematicians routinely use the skill of self-generation of examples to test and verify mathematical principles, theorems, and concepts, and yet the processes through which undergraduates learn to productively generate examples are not well understood. Students in multiple first-semester calculus courses participated in a teaching experiment designed to develop the mathematical skill of example generation and productive use of these examples to learn novel mathematical concepts. Through three iterations, a hypothetical learning trajectory was tested and refined to align with the actual learning observed in students. The findings showed that students participating in the teaching experiment became more self-directed, productive, and skillful example generators when learning novel mathematical concepts. The study provided evidence that the use of example generation is a plausible teaching method for introducing novel mathematical concepts in a first-semester calculus course. This presentation provides details of implementing example generation in a first-semester calculus course. In addition findings about changes in student attitudes towards learning mathematics through example generation will be discussed. (Received September 16, 2014)

1106-M1-1582 **Hiroko Kawaguchi Warshauer*** (hw02@txstate.edu), Texas State University, Department of Mathematics, 601 University Dr., San Marcos, TX 78666, **Christina Starkey Richardson** (cs1721@txstate.edu), Texas State University, Department of Mathematics, 601 University Dr., San Marcos, TX 78666, and **Max Leon Warshauer** (max@txstate.edu), Texas State University, Department of Mathematics, 601 University Dr., San Marcos, TX 78666. *Using Journals to Support Student Learning: The Case of an Elementary Number Theory Course.* Preliminary report.

This talk is based on a study that examined the use of journal writing by undergraduates in an Honor's Number Theory course and how the journals supported students' learning of number theory and proof writing.

The course allows students at different levels of mathematical maturity to participate and work together. It also provides a context for students to learn how to explore problems deeply and give careful, rigorous mathematical proofs. Students learn to explain their ideas both orally and in writing, and how to apply the mathematics learned to different types of problems.

The 17 undergraduates in this course submitted weekly journals online to their instructor and reflected on their mathematical learning. The instructor then provided comments to each of the students' journal submissions that informed him of each student's successes, challenges, issues, and questions. We analyzed the journals and share our preliminary findings on what the journal writing revealed about students' learning and how their mathematical understanding developed over a semester. In addition, we include results of the pre-post survey of student attitudes toward mathematics along with interviews of 4 of the students that give additional insight into their experiences in the course. (Received September 14, 2014)

1106-M1-2167 **Joy L. Becker*** (joy.becker@wartburg.edu) and **Jennifer L. Pothast** (jennifer.pothast@wartburg.edu). *Math Anxiety and Reading Strategies in Math Content Courses.* Preliminary report.

Students often experience math anxiety at various levels in lower-level mathematics courses, especially those required for general education programs. This research project, however, focuses on mathematics majors and pre-service teachers in math content courses. We investigated the use of reading strategies and processes, guided by reading quizzes and reflections, and their effects on students' anxiety levels, specifically related to problem solving and proof writing. Courses included a junior-senior level abstract algebra course and a math content course for pre-service elementary teachers. Anxiety levels were measured using a pre- and post-project survey, "Attitudes Toward Mathematics Inventory" developed by Martha Tapia in 1996, as well as written reflections from students. Results and potential applications of this project will be discussed. (Received September 15, 2014)

1106-M1-2247 **J. Lynn Gieger*** (lgieger@oglethorpe.edu), 4484 Peachtree Rd. NE, Atlanta, GA 30319, **Brian Patterson** (bpatterson@oglethorpe.edu), 4484 Peachtree Rd. NE, Atlanta, GA 30319, and **C. Rett McBride** (cmcbride@oglethorpe.edu), 4484 Peachtree Rd. NE, Atlanta, GA 30319. *The Impact of a Flipped Learning Environment on Student Attitudes and Achievement in a Liberal Arts Mathematics Course.* Preliminary report.

This study explored the effectiveness of a flipped pedagogy structure vs. a lecture-based structure in a Liberal Arts mathematics course. While flipped learning is partially defined as a pedagogical approach in which direct instruction moves from the group space to the individual (typically, but not necessarily, through the use of videos), this study focused on the effects of implementing the second aspect of the flipped learning definition—turning the group space into a more dynamic, interactive environment than is typically found in a lecture-based classroom. Students in four sections of the course were asked to read a portion of the text prior to class, with the only difference being that the two experimental sections used class time almost exclusively for problem solving and the two control sections used class time almost exclusively for lecture. The experimenters hypothesize that even this modest change in the course structure would show significant benefits both in student achievement and student attitudes about the course. Data sources include common assessment questions in Formal Logic and Probability, responses to the university-wide Student Response Survey, pre- and post-course responses on the Student Assessment of Learning Gains (SALG), and peer observation. (Received September 16, 2014)

1106-M1-2284 **Tharanga M.K. Wijetunge*** (tharanga.wijetunge@lyon.edu), **Kirthi Premadasa** and **Kavita Bhatia**. *The dreaded word problem: What do students remember?*

Math instructors usually provide a collection of word problems to accompany many topics taught in undergraduate mathematics, the motivation for which is to provide students with a glimpse of the real life applications these concepts may have. However it is a good question to ponder which (if any) of these examples will remain in the memory of the students at the end of the class, even in an outline or context form. We ask the question: Is there an underlying pattern to math application contexts that students remember (if any) at the end of a course delivery? Around 100 students in three liberal arts colleges located in Wisconsin and Arkansas took part in this study which was inspired by an earlier study which showed that in college algebra, given a choice, students highly significantly preferred word problems belonging to certain categories over others. Findings of our study will be presented during the talk. A longer retention of a mathematical application in memory can positively inspire a student towards mathematics. The emerging patterns will help educators in both high school and college to create an optimized collection of classroom and homework problems to present to when teaching certain topics. (Received September 16, 2014)

1106-M1-2338 **Sayonita Ghosh Hajra*** (sayonita@math.utah.edu), Department of Mathematics, University of Utah, Salt Lake City, UT 84112, and **Natalie Hobson** (natalielfh@gmail.com), Department of Mathematics, University of Georgia, Athens, GA 30602. *Exploring students' preferences and performance in a cooperative mathematics classroom.*

We will discuss our experience with cooperative learning in a mathematics content course. Twenty undergraduate students from a southern public university participated in this study. The instructional method used in the classroom was cooperative learning. The goal of our study is to investigate the relationship between students' preferences and performance in this cooperative learning setting. Results show no significant difference in the comparison of students' preferences and performance. Based on this study, we provide suggestions in teaching mathematics content courses for prospective teachers in a cooperative learning setting. (Received September 16, 2014)

1106-M1-2618 **Rachel M Chaphalkar*** (chaphalr@uww.edu), 2214 Laurentide Hall, 260 Carter Mall, Whitewater, WI 53190. *Introductory Statistics Students' Development of Reasoning about Variability.* Preliminary report.

Variability one of the key concepts in statistics, however in introductory statistics courses, students often struggle with understanding the concept of variability in graphs such as histograms (Cooper & Shore, 2008; delMas, Garfield, Ooms, & Chance, 2007; Turegun & Reeder, 2011). The purpose of this study is to understand how students' responses and reasoning about variability in histograms change during an introductory statistics course. Data were collected through a survey taken by 64 students at the beginning, middle, and end of an introductory course. Student responses to both multiple choice questions and short answer questions will be discussed. (Received September 16, 2014)

1106-M1-2765 **Ann C. Stewart*** (stewart@hood.edu). *Individual student confidence during classroom voting - what can the data tell us?*

Data on individual student confidence was collected during classroom voting in two different courses, with some overlap in students. While the data set is too small for a meaningful statistical analysis, there are still stories that it can tell. We will look at several different ways to interpret the data, and discuss some of the insights the results can give into individual student performance. (Received September 16, 2014)

1106-M1-2868 **Wes Maciejewski*** (wes@math.ubc.ca), 1984 Mathematics Road, The University of British Columbia, Vancouver, BC V6T 1Z2, Canada. *Do we know how students view mathematics and how they study it?*

It has long been known that the way a student views the subject they study affects the approach they take to studying the subject. This, in turn, affects their performance in the subject. It seems, then, that the improvement of student outcomes not only requires addressing the approach a student takes to study, but also their view of the subject. But do math instructors actually know how their students view math? This presentation will report results from a series of surveys intended to explore this question. Students in a variety of classes across all four undergraduate years completed the Conceptions of Mathematics Questionnaire (CMQ) and the Revised, Two-factor Study Process Questionnaire (SPQ). Instructors completed the CMQ as well, but were first asked to form an image in their minds of their archetypal student and respond to the survey as they think this student would. These instructor CMQ results were compared to the student average responses and a significant disconnect was found. As a second component to this study, SPQ scores were found to exhibit an interesting correlational structure with course grade that varied by course year. In this talk, I will present these results and explore implications for practice. (Received September 16, 2014)

1106-M1-2938 **Susie Kimport*** (susie.kimport@yale.edu) and **James S Rolf** (jim.rolf@yale.edu). *Flipping the Integral Calculus Classroom with Multiple Sections and Instructors.* Preliminary report.

In the Fall of 2014 we transferred a flipped classroom experience from one section to multiple sections with different instructors with varying degrees of experience. The main question we considered was "How do instructors with various backgrounds adapt to this new approach?" In particular, we wanted to know if the links between various pre-class and in-class activities would foster change in instructor teaching and attitudes. We present qualitative data from interviews and surveys. (Received September 17, 2014)

1106-M1-2939 **James S Rolf*** (jim.rolf@yale.edu) and **Susie Kimport** (susie.kimport@yale.edu). *Examining the Impact on Students of a Flipped Classroom with Multiple Instructors.* Preliminary report.

In the Fall of 2014 we transferred a flipped classroom experience from one section to multiple sections with different instructors. Every student watched common pre-class videos and answered common online preparatory problems. Individual instructors then tailored class based on pre-class activities and their own teaching style. Our main question was "How would students using a common set of pre-class activities but differing instructors respond to this approach?" We report data from surveys, focus groups, and exam performance to understand student learning behaviors, perceptions, and attitudes towards this experience. (Received September 17, 2014)

Statistics Education Beyond the Introductory Statistics Course

1106-M5-380 **Rick Cleary*** (rcleary@babson.edu). *Teaching the Background for Data Science and Analytics.*

While traditional statistical methods remain valuable and important, the era of big data has arrived, in which huge numbers of observations and variables can be stored efficiently at low cost. Many schools have responded by developing courses in analytics or data science. In this presentation we suggest some concepts and related activities that can be incorporated in traditional "Stat II" or "Statistics with Calculus" courses to help students be prepared for electives with a big data theme. (Received August 26, 2014)

1106-M5-416 **Barbara A Wainwright***, Dept. of Mathematics & Computer Science, Salisbury University, 1101 Camden Ave., Salisbury, MD 21801. *Opportunities for Statistics Students: Undergraduate Requirements, Research, Internships, and Future Employment.* Preliminary report.

Introductory statistics is now required or recommended for many undergraduate degrees. These courses should prepare individuals to at least be informed consumers of statistics, i.e., be able to read and understand research in their field. What about students who wish to focus on statistics as a possible career? This paper will describe the statistics curriculum for an undergraduate mathematics major with a concentration in statistics. This curriculum includes not only Mathematical Statistics I and II, but also intermediate courses in survey design and sampling and regression analysis as well as upper level courses in design of experiments and other advanced topics in statistics. All students in the program must also complete an internship or undergraduate research project. A discussion of some of these more recent interdisciplinary experiences that have been available to students will also be included. This presentation may be of interest to those wishing to develop an undergraduate program in Statistics or wish to involve students in interdisciplinary projects. (Received August 27, 2014)

1106-M5-680 **Nicholas J Horton*** (nhorton@amherst.edu), Amherst College, Mathematics and Statistics, Campus Box 2239, PO Box 5000, Amherst, MA 01002-5000. *The increasing role of data science in undergraduate statistics programs: new guidelines, new opportunities, and new challenges.* Preliminary report.

In a world of increasingly complex and sophisticated data, there is additional demand for graduates who are able to extract actionable information from it. They need to be able to "think with data" and undertake computation in a nimble fashion. Undergraduates need practice in utilizing all steps of the scientific method to tackle real research questions. The statistical analysis process involves formulating good questions, considering whether available data are appropriate for addressing a problem, choosing from a set of different tools, undertaking the analyses in a reproducible manner, assessing the analytic methods, drawing appropriate conclusions, and communicating results. To address this new challenge and opportunity, the American Statistical Association recently updated its guidelines for undergraduate programs in statistics. The new guidelines describe how undergraduate programs in statistics should emphasize concepts and approaches for working with complex data and provide experience in designing studies and analyzing real data. In this talk, I will provide background on the increasing number of undergraduate statistics majors and minors and discuss recommendations for curriculum revisions to help prepare these students to use data to make evidence-based decisions. (Received September 04, 2014)

1106-M5-744 **Laura A. McSweeney*** (lmcsweeney@fairfield.edu), Fairfield University, 1073 N. Benson Rd, Fairfield, CT 06824. *Statistics for Everyone: Integrating Statistical Reasoning on Campus.* Preliminary report.

As part of Fairfield University's campus-wide initiative to promote integrative thinking two faculty members, one from Mathematics and one from Psychology, created faculty development workshops titled "Statistics for Everyone". The goal of these two-day summer workshops was to help faculty from a wide variety of disciplines to incorporate statistics and promote statistical literacy in their core and major courses. Through lectures, hands-on exercises and using available technology, the workshop provided valuable background material and teaching resources so that faculty across campus could more confidently integrate statistics and statistical thinking into their specific classes. This presentation will highlight the resources and materials presented to the more than 40 workshop participants, including those in the sciences, humanities, social sciences and professional schools, and discuss some of the successes and challenges of this type of initiative. (Received September 05, 2014)

1106-M5-872 **Carolyn K. Cuff*** (ccuff@westminster.edu), Box 13, Westminster College, New Wilmington, PA 16172-0001. *Getting inside the black box of chemometrics: interdisciplinary research between statistics and chemistry.*

Chemometrics can be defined as analyzing measurements made on a chemical system or process via application of mathematical or statistical methods. Many such analyses are often done by chemists via a "black box approach." Chemists, then, often cannot explain the statistical process behind the analysis. With a good introductory statistics foundation, we believe students are capable of learning and explaining what is happening in the black box. Our chemometric work, a collaboration between math and chemistry students and professors, has focused on calibration curves. In undergraduate chemistry work, univariate calibration curves are typically used. They allow for the determination of concentrations of a single component (compound, element). Interactions between two components are harder to model, and the calibration curves are not as accurate as when there is no interaction. Principal component analysis can be used to create more accurate calibration curves and, therefore, better predictions of the concentrations. Our goal is to have students create the statistical analysis of the black box to determine the concentration of two heavy metals in frack water waste. This paper examines the successes (and frustrations) of the interdisciplinary work. (Received September 08, 2014)

1106-M5-1259 **Logan Tyler Soich*** (soichlo@ripon.edu), PO Box 248, Ripon, WI 54971, and **Chester Ivan Ismay** (ismayc@ripon.edu), PO Box 248, Ripon, WI 54971. *A Modified Team-Based Learning Approach to a First Semester Mathematical Statistics Course.*

Team-Based Learning (TBL) is often a recommended strategy in larger classrooms with teams consisting of 5-7 members per team. If the conditions are right, many of the ideas of this style of active student engagement can be applied to courses of smaller sizes as well. We will describe the preparatory work we completed in creating the background material for a TBL mathematical statistics/probability course. This work included developing short videos introducing probability concepts, creating an interactive applet using the `shiny` package in RStudio aimed at aiding students in visualizing probability distributions, and designing a bare bones textbook and solution manual in LaTeX. The students in the course worked in two small teams to solve the exercises provided in the textbook, added their own examples and explanations of concepts to better tie ideas together, and proved theorems. The overarching goal was for each team to create a textbook that encompassed their work and also described their progress in learning the course material. (Received September 15, 2014)

1106-M5-1632 **Sue B Schou*** (schosue@isu.edu), P O Box 4043, Pocatello, ID 83205. *Jazz Up Projects with Web Crawling.* Preliminary report.

To assess our students' understanding of regression, a group project requiring collecting real data is assigned. In an attempt to encourage students to use the latest technology available, students will be allowed to choose data collection from their chosen website by random sampling by hand or by using data extraction from all pages with web crawling. Groups will be paired based upon their data collection choice so they can compare their models; one based upon sampling, the other based upon what may be viewed as a population. This presentation will demonstrate the ease of use of the free web-based data extractor and web crawler. Student survey results concerning attitudes related to this project will be discussed as well. (Received September 15, 2014)

1106-M5-1786 **Dominic Klyve*** (klyved@cwu.edu). *Data from Everywhere, Analysis for All!*
This talk will describe efforts in an advanced statistics course to incorporate both real data and real stakeholders into the curriculum.

Students at Central Washington University have the option to take a second statistics course over two quarters. Topics covered include regression, ANOVA, and nonparametric models. Recently, the author has experimented with teaching these concepts primarily through the analysis of a large data set provided by a real stakeholder who needs results from the analysis. Students work together with the stakeholder to create a meaningful and useful end product. Results of these experiments – both the successes and the failures – will be shared. (Received September 15, 2014)

1106-M5-2358 **Mary Majerus*** (mary.majerus@westminster-mo.edu). *A Second Course in Undergraduate Statistics with an Interdisciplinary Approach.*
At our undergraduate liberal arts institution, there is a predominant expectation of upperclassmen completing research or internship experiences. In our department the introductory course in elementary statistics, which follows the Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report, has demonstrated effectiveness through assessment of course learning goals and objectives. This course, however, was not necessarily sufficient for students in the natural and social sciences who wished to engage more fully in undergraduate research. The departmental response to this was the design of a second course in statistical methods which required the introductory course as a prerequisite. The appeal of the course was to prepare students for more advanced research methods in their own disciplines in the subsequent year(s). Through this session, participants will learn of the course learning objectives, how those goals were met, and the interdisciplinary nature of the course and projects which ultimately served as one measure of success in the course. (Received September 16, 2014)

1106-M5-2501 **Judith E Canner*** (jcanner@csumb.edu), 100 Campus Center, Seaside, CA 93955. *How R You Using Statistics? Connecting the Second Statistics Course to Multiple Disciplines through Projects.*
Advanced statistics methods and the use of a statistics program often comprise the second course in statistics. Though a professor can vary example contexts, students need independent research experiences within their field of study to comprehend the true landscape of statistical investigation. I will overview the general course content of our second course, the use of R programming language within the course, and the preparation of students to learn new statistics methods and new R programming methods independent of classroom instruction. I will then discuss the use of a semester-long project to provide students with experience in statistical investigation and to assess their ability to apply their knowledge beyond the classroom experience. I will provide examples of how students broker relationships with other faculty or researchers in their fields to define a research question and evaluate provided data to produce a publication-ready paper. I will provide instruction on the necessary structure for the project, including benchmarks for progress throughout the semester, mentorship responsibilities of the professor and potentially other faculty, the allowance of co-authorship, and the final assessment of student work. (Received September 16, 2014)

1106-M5-2695 **John D Emerson*** (jemerson@middlebury.edu), Department of Mathematics, Middlebury College, Middlebury, VT 05753. *Statistical Computing: Strengthening Conceptual Understanding of Statistical Science.* Preliminary report.
Statistics as a discipline and in its routine practice relies on high-speed computation. Students of introductory statistics courses appreciate that computers are needed to implement the tests and other inferential procedures they encounter; these implementations often take the form of options in graphical user interfaces (GUIs). An introduction to a programming environment like R gives students the opportunity to experience first-hand some of the concepts that may have mystified them in the first course. A modest programming vocabulary enables students to carry out resampling, permutations, and bootstrapping, thus inviting them to experience concretely the meaning of such statistical concepts as sampling distributions, type-I error and power, and empirical densities. This paper is based on experience at a liberal arts college with a course offered to students having varied backgrounds and diverse expertise. Student teams took advantage of these backgrounds, and the course was largely built around team projects and, sometimes, open-ended investigations. The goals of the course and its projects shaped the computer programming component (in R) of the course. Students encountered challenges of "big data" problems, and they learned first-hand the meaning of reproducible research. (Received September 16, 2014)

1106-M5-2822 **Rebecca Nugent***, rnugent@stat.cmu.edu. *Choose-Your-Own Capstone Adventure: Providing Flexible Paths for Undergraduate Statistics Majors.*

Recently, the ASA has devoted extensive effort to updating undergraduate Statistics curriculum guidelines. One focus is the role and variety of undergraduate Statistics capstones, traditionally defined as a final culminating experience synthesizing coursework and skills for all students. But what if there are too many? As elsewhere, the Carnegie Mellon Statistics major has exploded in size relative to other majors, growing by about 500% in five years. In addition, other programs such as Mathematics and Machine Learning also require our capstone courses. To provide a high level of quality and feedback requires a Herculean effort. Furthermore, students headed to industry require markedly different training than those headed to graduate school. At CMU, we are developing a framework that provides different capstone experiences depending on students' individual goals and talents. Our hope is that this flexibility will help align students with experiences that fit their career paths and alleviate faculty burden. This talk will focus on our program's progression to its current flexible form with an added emphasis on research experiences and fun competitions. We summarize the chosen student paths as well as student feedback about their Choose-Your-Own Capstone Adventures. (Received September 16, 2014)

Teaching Inquiry

1106-N1-377 **Peter Lawson Maceli*** (plm2109@columbia.edu). *Graph theory by example.* Preliminary report.

For the past two years, I have been teaching a class in graph theory for high school students as part of the Columbia University Science Honors Program. Since graph theory is such an accessible and visual field of mathematics, it provides an ideal setting for a class where the main focus is on developing mathematical intuition and instinct. Questions, problem solving, and student examples drive the course, which is structured more as a guided exploration rather than lecture. Many deep concepts and ideas in graph theory are illustrated by small graph examples. Allowing students the freedom to make these discoveries themselves helps them develop a new perspective on the roles creativity and ingenuity play in the mathematical process. In this talk, we describe several lessons from the course, which explore some non-traditional topics from graph theory. (Received August 26, 2014)

1106-N1-382 **Victor I Piercey*** (piercev1@ferris.edu) and **Roxanne Cullen**. *Using Linked Courses and Classroom Configurations to Teach Mathematical Inquiry to Freshman Business Students.* Preliminary report.

First year undergraduate business students, like other college freshmen, usually expect to be told in class what they need to know for "the test." They tend to resist posing questions unless it relates to how they do their homework. However, posing and investigating questions is a lifelong learning skill that is particularly important for business professionals.

In this talk, we will share attempts to stimulate question-asking and exploration in an inquiry-based quantitative reasoning course for business students. We ran two sections of this course. One section was linked with a freshman writing course and took place in a classroom whose configuration was designed to encourage inquiry. The other section was unlinked in a standard classroom. We will discuss the assignments designed to promote question-asking in both the linked and unlinked sections as well as data comparing the two sections. The data include the frequency and quality of questions posed in each class and results of a math anxiety and math beliefs survey administered to both sections at the beginning and end of the course. (Received August 26, 2014)

1106-N1-554 **Jacqueline Jensen-Vallin*** (jacqueline.jensen@lamar.edu). *Teaching College Algebra Students to Formulate Questions.* Preliminary report.

We know it is beneficial to train students to think critically and mathematically during their early mathematical lives. To this end, I teach Intermediate Algebra and College Algebra in an inquiry-based learning style. The students read the textbook before class and formulate questions about the material to be covered in class the next day. During class they solve problems about that topic, and solutions are presented and discussed before the end of the period. After class they then complete standard homework about the topic, and are encouraged to bring any unresolved homework, worksheet or reading questions for the next class period. We will discuss this method of engaging students, focusing on how student questions evolve during the semester, and on student feedback. (Received September 02, 2014)

1106-N1-671 **Estrella MS Johnson*** (strej@vt.edu), 460 McBryde Hall, 225 Stanger, Virginia Tech, Blacksburg, VA 24061. *Critical Components of Inquiry-Oriented Teaching.*

Over the last decade, undergraduate mathematics researchers and curriculum developers have generated inquiry-oriented curriculum materials for courses from calculus through abstract algebra. Here, we take inquiry-oriented to describe both the student and the teacher's role in the classroom. Students "learn new mathematics through inquiry by engaging in mathematical discussions, posing and following up on conjectures, explaining and justifying their thinking, and solving novel problems", while "teachers routinely inquire into their students' mathematical thinking and reasoning" (Rasmussen & Kwon, 2007, p. 190). The work represents our efforts to define and map the domains of inquiry-oriented teaching. Specifically, by drawing on empirical and theoretical research on inquiry-oriented teaching, and by analyzing classroom video data, we will present a list of critical components for inquiry-oriented teaching. These critical components will be illustrated and exemplified by analyzing inquiry-oriented classroom video data. (Received September 04, 2014)

1106-N1-672 **Jennifer Nordstrom*** (jfirkins@linfield.edu). *Using Game Theory to Foster Inquiry and Writing.* Preliminary report.

Linfield College requires an Inquiry Seminar of all first-year students. The purpose of this course is to introduce students to academic discourse through writing. As the course title suggests, it motivates writing as a means of posing interesting questions and providing reasoned arguments to answer these questions. Faculty members from all disciplines teach Inquiry Seminars, focusing on themes they find particularly interesting. Although undergraduate mathematics, as a discipline, may seem miles away from undergraduate writing, especially in first-year courses, this talk will focus on the success of a first-year writing course with the theme of mathematical game theory. Mathematics provides a robust framework for students to explore questions of rationality, value, cooperation, and societal versus individual good. Such questions can engage students with wide-ranging interests and backgrounds in mathematics. We will discuss how educational approaches familiar to mathematicians coincide with those of writing faculty, and how these pedagogical methods can be used to encourage students to develop habits of inquiry that can apply to all disciplines. (Received September 04, 2014)

1106-N1-841 **Robert E Buck*** (robert.buck@sru.edu), Department of Mathematics, Slippery Rock University, Slippery Rock, PA 16057. *Experiments in Conjecturing.*

Our department requires students to take a seminar on a topic not covered in standard mathematics courses. I chose to discuss Continued Fractions since it sounded like something the students would find interesting and I knew little about the topic.

At the first meeting, I gave the basic definitions and did a few examples. After each session, there was a three part assignment. Part 1 consisted of different types of computational problems. Part 2 was always the same: Make at least one conjecture based on the computations from Part 1. Part 3 asked them to prove or disprove at least one of the previous conjectures.

During the class discussion, students were expected to argue for their conjectures (as opposed to proving them). At the start, conjectures tended to be sweeping ("All . . ."). Students needed help with the idea of hypotheses. Sometimes this was done during the class discussion, or someone would give a counterexample that narrowed the scope of a conjecture. By the end of the term they got the idea of stating conditions.

The students spent a lot of time discussing the material, both in and out of class. I feel that the seminar was a successful experiment in giving the students a taste for creating mathematics on their own. (Received September 07, 2014)

1106-N1-893 **Lara Pudwell***, Department of Mathematics and Statistics, 1900 Chapel Drive, Valparaiso, IN 46383. *Teaching Inquiry through Experimental Mathematics.*

Since 2009, Valparaiso University has offered a junior-level course in Experimental Mathematics as an elective for mathematics majors and minors. Rather than focusing on a particular list of content, the goal of this course is to cultivate an attitude of exploration in students' approaches to new problems. Along the way students learn basic programming using a computer algebra system and work on independent research projects throughout the semester. This talk will describe the setup of the course and give particular examples of experimental class activities. (Received September 08, 2014)

1106-N1-1083 **Angie Hodge*** (amhodge@unomaha.edu), NE, and **Janice Rech** (jrech@unomaha.edu), **Faan Tone Liu**, **Kimberly Bunning**, **David Webb**, **Eric Stade** and **Ron Tubbs**. *Teaching Inquiry through Calculus TACTivities.*

Calculus is often thought to be a course where students learn a specific skill set. Limits, derivatives, and integrals are all topics that are covered and hopefully learned in a standard calculus course. It is not often in a calculus

course that one thinks about learning how to ask good mathematical questions and explore these questions. In this session, we will share activities that are tactile, hands-on, and engage the students while at the same time teaching them the basic skills of calculus. The activities being created for the calculus series are designed to teach students to explore mathematical ideas without a teacher telling them what to do. The results of the piloting of these tactivities at two universities will also be shared. (Received September 13, 2014)

1106-N1-1285 **Diana White*** (diana.white@ucdenver.edu). *Using a Non-Traditional Mathematical Operation to Teach Inquiry.*

Problem posing and mathematical exploration are key disciplinary components of mathematics, yet they are often overshadowed by the push to cover content. In this talk, we discuss an open-ended mathematical problem that has been used repeatedly by a variety of mathematicians in both undergraduate mathematics courses and professional development workshops for teachers. We provide an overview of the problem, discuss how it leads naturally to problem posing, mathematical exploration, conjecturing, communication, and level-appropriate rigorous mathematical argumentation. We also point out how it crosses into a variety of mathematical content areas and connects up with ongoing mathematical research. Finally, we provide a brief qualitative overview of survey results from students regarding the impact of these types of problems on their perspective of mathematics. (Received September 11, 2014)

1106-N1-1385 **Stan Yoshinobu*** (styoshin@calpoly.edu). *Teaching Inquiry in a Capstone Course for Future Secondary School Teachers.*

Math courses for future teachers are arguably the most important math courses we teach. Teaching the full spectrum of inquiry is especially important for those entering the teaching profession. The current challenge is to provide prospectives teachers, who may have never experienced inquiry, opportunities to experience inquiry, to understand the merits of inquiry, and to prepare them so that they could one day teach via inquiry. Such lofty goals are difficult to achieve, but are worthwhile to pursue. In this talk, the design and implementation of a capstone course for future secondary school math teachers are discussed that attempts to start to address the described challenges above. (Received September 12, 2014)

1106-N1-1437 **Aaron Wangberg*** (awangberg@winona.edu), 322 Gildemeister Hall, Department of Mathematics and Statistics, Winona State University, Winona, MN 55987, and **Brian Fisher** (brian.fisher@lcu.edu), **Jason Samuels** (jsamuels@bmcc.cuny.edu) and **Eric Webber** (eric.weber@oregonstate.edu). *Raising Calculus to the Surface: Discovering geometric connections behind multivariable calculus.* Preliminary report.

The multivariable setting introduces extensions to many major themes of single variable calculus. The algebraic conditions necessary for these new theorems are often quite subtle but have beautiful geometric interpretations. We have developed physical surfaces, measurement tools, and activities which help students discover potential connections across the multivariable calculus curriculum. We will share how these materials help groups of students formulate and share their own conjectures with the class as well as test the conjectures of their peers before formal lecture. In this talk, we will demonstrate how these materials let students explore the relationship between the geometric features of contour plots and the value of various single, double, and triple integrals. Raising Calculus to the Surface is funded in part by the National Science Foundation DUE #1246094. (Received September 13, 2014)

1106-N1-1502 **Yuanying Guan*** (guany@iun.edu), Department of Mathematics, Indiana University Northwest, 3400 Broadway, Gary, IN 46408. *Apply inquiry-based mathematical teaching in actuarial science classes.*

Inquiry-based learning has been widely used as a teaching and learning tool in developing students' critical thinking skills. While mathematics is perceived as one of the most abstract subjects, actuarial science is an excellent outlet for applying mathematical theories to exploring and solving real life problems. Therefore, the inquiry-based mathematical teaching proves to be a really important part of these courses. In this paper, the author will use some examples in core actuarial courses, such as Probability and Financial Mathematics, to illustrate the methods of teaching students to ask and explore mathematical questions in actuarial science classes.

(Received September 13, 2014)

1106-N1-1659 **Michael Starbird*** (starbird@mail.utexas.edu), Department of Mathematics, RLM 8.100, The University of Texas at Austin, 2515 Speedway, Stop C1200, Austin, TX 78712. *Lessons that Last–Teaching Effective Thinking.*

Mathematics courses are most often described in terms of their mathematical content. But the lessons that students retain forever frequently include attitudes about and habits of inquiry, curiosity, and effective exploration of the unknown. A basic challenge for us as educators is to design class experiences that systematically instill in students effective thinking habits that last a lifetime. (Received September 14, 2014)

1106-N1-1806 **Samuel Cook*** (scook25@uaa.alaska.edu) and **Nicole Seaders** (seadersn@math.oregonstate.edu). *To Each Their Own: A Semester Project Emphasizing Continuous Conceptual Involvement and Inquiry.*

The project described below arose from an attempt to find a way to give students some ownership over their learning, involve them at every step, and infuse them with the joy and challenge of discovery and research. Students are assigned individual objects to study throughout the term, using the techniques presented in class as the tools of their discovery. Students learn to ask and explore mathematical questions about their individual object and investigate questions of personal interest. Solutions to problems encountered in initial trials of the project are discussed. (Received September 15, 2014)

1106-N1-1854 **Teena Carroll***, PO B0x 947, Emory, VA 24327. *Using Games as a Invitation for Inquiry.*

Students are most invested in answering questions that they pose themselves; However, posing questions is a skill that does not come naturally to most students and is not universally encouraged in classrooms. In order to get students to pursue deep questions, you need to both provide a setting which sparks curiosity and an environment which values pursuit of the answers.

In this talk I will outline how I used the board game Ticket to Ride to inspire the direction of a discrete structures class. At the beginning of the semester students learned how to play the game (which takes places on a board which is an edge-colored graph representing potential train connections between cities in the United States.). As a class, they made a list of questions about the game. During the rest of the semester, we learned the mathematics we needed to answer these questions using a set of IBL notes. We selected topics according to their usefulness towards the initial list of questions. Our list inspired the investigation of spanning trees, Steiner trees and shortest path algorithms. The class found an innovative strategy for winning the game. (Received September 15, 2014)

1106-N1-1888 **Anne M Cawley*** (acawley@umich.edu), 610 E. University Ave, SEB 4002, Ann Arbor, MI 48109, and **Vilma Mesa** (vmesa@umich.edu), 610 E. University Ave, Ann Arbor, MI 48109. *Faculty Knowledge of Teaching in Inquiry-Based Learning Mathematics.* Preliminary report.

In the context of using Inquiry-Based Learning (IBL) for teaching, over 70 instructors teaching a wide range of university mathematics courses and with various levels of familiarity with IBL filled out bi-weekly logs about the challenges they had teaching with these strategies and the solutions they had found. The analysis of these pairs of concerns and solutions expressed over the three-year study reveals, unsurprisingly, that faculty draw from different domains of teacher knowledge for teaching to solve concerns that arise as IBL is implemented in their classrooms. We see, however, differences depending on the type of work the teacher needs to do, and a weak link due to their level of familiarity with IBL. A further specification of the nature of this knowledge in the different areas in which teaching is manifested is needed. (Received September 15, 2014)

1106-N1-1987 **Joseph W. Eyles*** (jeyles@gordonstate.edu). *TRIGONometry : An Inquiry of Triangle Measurement.* Preliminary report.

Often students arrive in a college level pre-calculus class with varied backgrounds in geometrical thinking. Some states' school curricula specify an algebraic treatment to high school geometry and recent textbooks relegate constructions with a compass and straight-edge to enrichment activities instead of the fundamental exercises. So, trigonometry, measuring triangles, has become essentially an abstraction to students today instead of the practical skill that it has been through the millennia. This presentation will focus on activities developed to enhance students' trigonometrical thinking through inquiry and practical applications. (Received September 15, 2014)

1106-N1-2035 **RaKissa D Cribari*** (rakissa.cribari@ucdenver.edu), University of Colorado Denver, Campus Box 170, P.O. Box 173364, Denver, CO 80217-3364. *Distinguishing Mathematical Definition by Doing the Coochy Coo.*

Most students believe that definitions play an important role in the learning of mathematics. However they struggle with transitioning from performing procedures to reasoning from definitions as they move into more sophisticated mathematics. Further, students tend to rely primarily on their concept image and intuition about a concept, especially visual/mental images, instead of the concept definition. The issue of limited concept images and the lack of a strong connection between a concept image and its mathematical definition need to be addressed at all levels of study in undergraduate and secondary mathematics. The goal of this session is to present an activity designed to help students focus in on the concept definition while isolating their natural inclination to rely solely on their concept image when working on a mathematical task. (Received September 15, 2014)

1106-N1-2095 **sarah-marie belcastro*** (director@mathily.org). *Ask questions to encourage questions asked.*

Among our many educational goals are that we want students to pose appropriate questions, and we want students to initiate exploration of those questions; indeed, we want inquiry and exploration to become habits of mind.

One effective way to inculcate these habits is to embed structured practice of these skills into every class. An instructor can model the asking of questions and the initiation of explorations. S/he can request explicitly that students ask questions and can prompt students to initiate explorations. By having students share questions, an instructor can guide students in evaluating the potential fruitfulness of those questions. An instructor can provide spaces so students can realize on their own that there are questions to be asked, or that exploration is the next step. The implementation of such modeling, requests, guidance, and timing is both nuanced and instructor-specific; discussion of these aspects will be the focus of the talk.

Additionally, how structured inquiry-skills practice might be incorporated into a class depends on context. We will give examples of implementing these techniques in an IBL-influenced calculus class, in a partially IBL mathematics for liberal arts class, and in a completely IBL class for gifted high-school students. (Received September 15, 2014)

1106-N1-2096 **Martha H Byrne*** (byrnema@earlham.edu), Earlham College, Drawer 138, 801 National Rd W, Richmond, IN 47374. *Using Games to Engage Students in Inquiry.*

The success of inquiry-based learning courses rests upon the engagement of the students; they have to want to understand in order to work with the material at the level that will promote understanding. This talk will focus on sharing the mathematics of games as discovered in an inquiry-based course at a small, liberal arts college. In the course, students formed conjectures and sought resolution as individuals with the support of the instructor and the classroom community. The mathematics addressed will include modular arithmetic, geometry, binary operations, and graph theory. The presenter will share ideas on how to get students to engage with these mathematical topics through inquiry in the context of exploring several well-known games. (Received September 15, 2014)

1106-N1-2113 **Randy Ryan Davila*** (rrd6@rice.edu) and **Sharon K Strickland**. *Definition Construction and Developing Mathematical Inquiry.*

In this session we will present a small unit designed to encourage students to define, conjecture and (dis)prove their own "kind" of numbers and evidence of student success (and struggles) with the unit. Although the students were preservice middle school math teachers, the unit could be used in other courses at or beyond a college algebra level. After introducing some properties of integers such as commutativity and closure, as well as the 2k+1 and 2k forms of odds and evens, students were asked to construct their own "kind" of number (e.g. Apple Numbers are of the form 3n+7 where n is an integer). Students then conjectured about their numbers and (dis)proved their conjectures. Common conjectures involved closure and whether the "kind" of number was a multiple of some factor. Minimal instruction related to proving was included because this group had no formal proof background. After engaging in their own definition construction for several classes, the students began to conjecture more advanced material like the twin prime conjecture. Overall, the results suggested that they struggled to prove their conjectures but were able to develop many conjectures and seemed to adopt a shift in their thinking towards questions of the sort, "What if" and "Maybe it's true that." (Received September 15, 2014)

1106-N1-2118 **Volker Ecke*** (vecke@westfield.ma.edu), **Christine von Renesse**, **Julian Fleron** and **Philip K Hotchkiss**. *Discovering the Art of Inquiry: Creating a Culture of Asking Open Questions.* Preliminary report.

What is needed to support students in cultivating lifelong habits of curiosity? We claim that students will naturally start asking interesting questions if the majority of what they see or hear in their class are questions: course materials dominated by questions rather than facts, a teacher who answers questions with questions, and a classroom where questions focus the day to day work of the group. In this "talk", participants will explore, share, and inquire into tools and activities that can support a culture of inquiry. Discovering the Art of Teaching IBL (artofmathematics.org/classroom/) is a growing collection of pedagogical tools we are learning about for creating a culture of inquiry in our mathematics classes. Discovering the Art of Mathematics (artofmathematics.org) is an NSF-funded project to develop inquiry-based course materials and to provide pedagogical resources to make inquiry-based learning come alive in mathematics courses for liberal arts majors. (Received September 15, 2014)

1106-N1-2123 **Kristin A. Camenga*** (kristin.camenga@houghton.edu). *Extending mathematical problems.* Preliminary report.

As mathematicians, we often create new problems by extending our recent work: considering further cases, generalizing, or exploring a new direction uncovered by solutions to previous problems. In this talk, we will discuss two assignments that ask students to pose their own problems by extending their work on assigned problems. One assignment is from a discrete mathematics course typically taken by sophomores and one is from the capstone course for the mathematics major. We will share the assignments, how students have performed and comments they have made, and compare how the expectations and performance varies between the courses. (Received September 15, 2014)

1106-N1-2229 **Debra L Mimbs*** (dmimbs@leeuniversity.edu), 1120 North Ocoee Street, Cleveland, TN 37320. *Using Journaling to Promote Inquiry.*

Teaching the skill of inquiry to our undergraduate students is becoming more important, yet it is a difficult skill to teach, and traditional methods of teaching mathematics often fall short of this goal. The practice of journaling in class can help promote inquiry. It can also be a valuable tool when researching with students. This talk will discuss using journaling as a technique to encourage inquiry in both entry level classes such as College Algebra and Calculus and in the process of teaching students to perform independent research at the undergraduate level. (Received September 16, 2014)

1106-N1-2333 **Samuel A. Cook*** (scook@wheelock.edu), **Debra K Borkovitz** (dborkovitz@wheelock.edu) and **Galina Dobrynina** (gdobrynina@wheelock.edu). *How Students Experience a Mathematics Program with an Inquiry-Based Philosophy.* Preliminary report.

The mathematics department at Wheelock College has a strong focus on teacher education, including a mathematics major for prospective preK-8 teachers. The department has a commitment to inquiry-based pedagogy within all our courses, as we know that teachers' default is to teach as they were taught, and most of our students had little previous experience with inquiry-based learning before coming to Wheelock. There are many resources to support inquiry-based pedagogy in introductory courses for prospective teachers, but implementing more advanced inquiry-based courses for this population is less charted territory and hence more challenging.

This talk will discuss a small qualitative study of students' struggles and advances through a major committed to inquiry-based pedagogy, with an emphasis on students' experiences in courses such as Algebra & Number Theory, Geometry, and Probability & Statistics. (Received September 16, 2014)

1106-N1-2339 **Theron J Hitchman*** (theron.hitchman@uni.edu), Department of Mathematics 0506, University of Northern Iowa, Cedar Falls, IA 50614. *Nurturing Inquiry in a Moore Method Geometry Classroom.*

A (Modified) Moore Method classroom is normally viewed as a place where students learn to answer questions rigorously, but it also serves as a good platform for teaching students how to ask questions the way a mathematician does.

We will discuss several practical ways in which this can be done, illustrated by actual classroom events in the author's Euclidean Geometry course. We shall discuss how careful construction of a class task sequence, a few "presentation management" techniques, and a healthy respect for students can be combined to welcome students into the community of mathematical exploration. (Received September 16, 2014)

1106-N1-2426 **Valerie J. Peterson*** (petersov@up.edu). *Homework Presentations in Calculus I.*
With an eye toward improving technical communication and shifting (perceived and actual) mathematical authority to students, homework presentations have been employed in a Calculus I course over several semesters. Presentations are student led, whole class discussions that occur once a week; class consensus determines when a problem is finished. Informal evidence suggests a variety of student benefits, including improved written and oral communication skills and increased engagement with homework. This talk will present rationale for student presentations, tips for implementation, and preliminary outcomes related to student attitudes and skills. (Received September 16, 2014)

1106-N1-2478 **Suzanne Ingrid Doree*** (doree@augsburg.edu), Augsburg College Campus Box 61, 2211 Riverside Avenue, Minneapolis, MN 55454. *What do you notice? Using conjecturing activities to teach inquiry and ignite student's curiosity about mathematics.*
What happens next? Does it always work? What if we tried this instead? How many are there? These sorts of questions are part of any mathematician's toolkit. We are well trained in the skill and art of inquiry. But how do we ignite students' curiosity and help them develop this ability?

For the past fifteen years I have taught a sophomore level discrete mathematics course that teaches inquiry through conjecturing activities. After all, conjecturing is at the core of what mathematicians do – it is our research experiment, our way of thinking through an abstract question, and prelude to developing a theory. Teaching conjecturing helps students grow their inner mathematicians, preparing them for advanced courses and undergraduate research. But the benefits extend beyond. Conjecturing activities ignite student's curiosity and develop their ability to inquisitively explore new ideas. As an added bonus, students enjoy making conjectures and so they spend a lot of time working on classwork in and out of class and they are more likely to persist in their study of mathematics.

In this talk I'll describe why we teach conjecturing and illustrate several successful mathematical conjecturing activities and reflections on what makes these activities work. (Received September 16, 2014)

1106-N1-2639 **Dana C. Ernst*** (dana.ernst@nau.edu) and **Nandor Sieben** (nandor.sieben@nau.edu). *Transitioning students from consumers to producers.* Preliminary report.
In response to assessment reports identifying weaknesses in communication and reasoning of junior and senior mathematics majors, we have developed a 3-credit semester-long course that is required for all first-year mathematics majors. The focus of this course is on reasoning and communication through problem solving and written mathematical arguments in order to provide students with more experience and training early in their university studies. The goal is for the students to work on interesting yet challenging multi-step problems that require almost zero background knowledge. The hope is that students will develop (or at least move in the direction of) the habits of mind of a mathematician. The problem solving of the type in the course is a fundamental component of mathematics that receives little focused attention elsewhere in our program. The course will be taught via an inquiry-based learning (IBL) approach with an explicit focus on students asking questions and developing conjectures. In this talk, we will describe the structure of the course and our plan for transitioning students from "consumers" of mathematics to "producers". (Received September 16, 2014)

1106-N1-2676 **Theresa A. Jorgensen*** (jorgensen@uta.edu). *Engaged Calculus - Building Community-Centered Inquiry into a First Semester Calculus Course.* Preliminary report.
We describe the implementation of Engaged Calculus at the University of Texas at Arlington. In this section of Calculus I, populated by primarily first-time, full-time freshmen, students developed and explored research questions that they could investigate utilizing the mathematical tools of calculus which they were simultaneously learning in the course. Their research questions were all based in issues they chose related to their university community, thus requiring them to become more fully engaged as UT Arlington Mavericks – for example, one group modeled the laundry machine availability in the dorms on campus to predict the best times to do laundry. These research projects, completed in groups of 4 or 5 students, spanned the entire semester, and culminated with written reports and poster presentations. We describe both the structure of the course including the timeline for the projects, the supports that were provided as the students collaboratively developed their research questions, and how this focus on mathematical inquiry influenced the student outcomes in terms of their calculus skills and understanding, and their attitudes about how real-world problems can be better understood using mathematics. (Received September 16, 2014)

1106-N1-2722 **Elin Farnell*** (farnelle@kenyon.edu), Department of Mathematics and Statistics, Kenyon College, Hayes Hall, 201 N College Rd, Gambier, OH 43022. *Puzzle Pedagogy: Riddles and Their Value in Mathematics Education.* Preliminary report.

Logic puzzles and riddles have long been sources of amusement for mathematicians and the general public, alike. In recent history, they have taken a prominent role as standard interview questions, especially within the technology industry. I propose that puzzles can serve a useful role in a classroom setting as a basis for discussion of the nature of mathematics, for development of problem-solving skills, and as a means of engaging students from a broad range of mathematical backgrounds. In particular, I suggest that puzzles be used as a tool for encouraging curiosity, creativity, and persistence, both within the classroom setting and in the practice of mathematics more generally. In this talk, I will present a collection of puzzles and discuss underlying concepts that contribute to the development of students' mathematical inquiry. (Received September 16, 2014)

1106-N1-2744 **Steven Greenstein*** (greensteins@mail.montclair.edu), **Catherine Buell** (cbuell1@fitchburgstate.edu) and **Zahava Wilstein** (zwilstein@berry.edu). *Methods for Democratizing Inquiry for K-16 Students and Teachers.*

After designing and implementing a professional development workshop for middle and high school teachers focused on incorporating Inquiry-Based Learning (IBL) into their teaching, we found that despite their good faith attempts to implement traditional methods of IBL, inquiry did not readily manifest itself in their classrooms. Consequently, we endeavored to unearth inquiry's theoretical foundations and their implications for teaching in order to promote an inquiry orientation and a more equitable mindset that democratizes access to authentic mathematical activity by honoring the diversity of students' mathematical knowledge. We believe such an approach not only allows students to realize the benefits of an inquiry orientation for learning mathematics, but also develops their ability to understand and possibly influence "real" problems that exist outside the classroom and in their communities. In this talk we will emphasize the significance of teachers' and students' beliefs about mathematics and about learning. We will also share examples of activities that emphasize the centrality of mathematical tasks in helping teachers cultivate an environment of inquiry and equitable access. (Received September 16, 2014)

Technology, the Next Generation: Integrating Tablets in the Mathematics Classroom

1106-P1-86 **Cynthia J. Huffman*** (cjhuffman@pittstate.edu). *Using iPads in Applied Abstract Algebra.* Preliminary report.

Many students are visual learners. Although abstract algebra is very theoretical, certain concepts can be explored visually, and the iPad is a useful tool for doing so. During the Fall 2014 semester, the presenter participated in a university iPad project which provided each student in an Applied Abstract Algebra course an iPad for use throughout the semester. In this presentation, we will discuss from where the funding for the iPads came, how the iPads were used in the course, apps that the students found useful, and the success of the project. (Received July 07, 2014)

1106-P1-719 **Jacci White*** (jacci.white@saintleo.edu), **Scott White** and **Brian Camp**. *iPad/laptop/Surface/smartphone: how do you choose?* Preliminary report.

In this session we will explore advantages and disadvantages of such criteria as size, access to mathematical software, use as a student response system, and controlling the classroom environment. We will compare uses in a traditional classroom versus the online environment as well as for leading the class versus student use. Examples will include use as a student response system; use to control the traditional computer and projector or Smartboard; use of statistical software; classroom presentations; and accessing typical online resources such as discussion boards, interactive problem sets, and chat rooms. (Received September 05, 2014)

1106-P1-1311 **Janet Sharp*** (janet.sharp@washburn.edu), 250H Morgan Hall, Washburn University, Topeka, KS 66621. *Dynamic Representations as a Conceptual Foundation for Defending non-Traditional Procedures in a Subtraction Algorithm.*

When learners create representations of mathematical ideas and processes, they develop understandings of mathematics and essential elements of communication of mathematical ideas. A good representation can strengthen conceptual knowledge. Electronic technology has the capacity to allow representations to be dynamic in nature, rather than static, and this advantage allows representations to more closely correspond with real-time step-by-step mathematical procedures. The iPad application, educreations, allows students to demonstrate conceptual and procedural knowledge in a dynamic manner, and capture those thoughts with a video record of thinking that can be revisited later. Such animated representations hold promise for redefining how a learner represents mental ideas. Educreations is user-friendly and lends itself to creating and storing the final representations. This paper describes results of two different groups of K-8 prospective teachers who experienced different kinds of lessons about subtraction during their elementary mathematics content course. The assessment task required students to analyze a child's static written record of her invented subtraction procedure and use their conceptual knowledge to justify the generalizability of the algorithm's procedures. (Received September 12, 2014)

1106-P1-1755 **Gulden Karakok*** (gulden.karakok@unco.edu), **Aaron Wangberg** and **Nicole Engelke**. *WeBWorK CLASS: Using tablets to capture authentic student work for classroom discussion.*

WeBWorK CLASS (Collaborative Learning and Active Support System) is created by combining features of the online homework system WeBWorK with a digital whiteboard to enhance formative assessment and in-class problem solving activities using tablets. CLASS facilitates student engagement by offering students authentic problem-solving activities. Students submit their final answers in WeBWorK and the whiteboard area records their written work. From these solutions, the instructor can choose ones that illustrate a misconception, a common error, an elegant solution, etc. and then display these solutions anonymously for discussion in the current or subsequent lesson. In this presentation, we will share how these discussions allow students to gain a deeper understanding of the material and an appreciation for the need of clearly showing one's thought process in the context of learning related rates problems. (Received September 15, 2014)

1106-P1-2258 **Daniel R Moseley*** (dmosele@ju.edu), Department of Mathematics, Jacksonville University, 2800 University Blvd N, Jacksonville, FL 32211. *Incorporating iPads and Apple TVs in the classroom.* Preliminary report.

Recently, the mathematics department at Jacksonville University received a technology gift that we have used to incorporate iPads in conjunction with Apple TVs in each classroom. We will document the classroom configurations, the software and apps we have tried, and a few unconventional uses we have discovered for this system. We will also discuss the challenges we have encountered as well as some technical detail of the configuration. (Received September 16, 2014)

1106-P1-2357 **M. Reba*** (mreba@clemson.edu), Department of Mathematical Sciences, Martin Hall, Clemson University, Clemson, SC 29634, and **A. Guest**, **M. Burr**, **R. Pargas**, **C. Williams** and **T. Khan**. *Calculus and Mobile Apps: Mathematics Partnering with Computer Science to Provide Informal Learning Opportunities.* Preliminary report.

Through two NSF grants, the Department of Mathematical Sciences collaborated with the School of Computing (1) to use technology, both inside and outside the calculus classroom, in order to increase learning opportunities for at-risk STEM students, and (2) to identify biomedical and bioengineering applications of calculus by forming alliances with other departments and other universities. Our current focus is the result of these efforts. We are building two sets of mobile apps (one for Apple iPads and another for Android tablets) that will provide to under-performing and under-represented students opportunities to revisit certain calculus concepts and to explore calculus applications. The mathematical content in the apps is presented in conjunction with the calculus classroom. One set of mobile apps will focus on six areas of Calculus I in which errors occur most often (based on an extensive error-analysis of final exams). The second set of apps will investigate the use of calculus in areas such as Epidemiology, Orthopedics, Radiology, and Heat Propagation. These apps are based on materials developed in Creative Inquiry courses at Clemson and partnering universities. We will discuss our efforts on this project as well as demonstrate one or more of the apps. (Received September 16, 2014)

1106-P1-2732 **Anders O.F. Hendrickson*** (anders.hendrickson@snc.edu), Department of Mathematics, St. Norbert College, 100 Grant St, De Pere, WI 54115. *Mobile apps for teaching empirical probability.*

Some well-known classroom demonstrations of empirical probability (e.g., drawing candy from a bag) can take up significant amounts of class time. We describe a class activity that achieves the same pedagogical result in much less time. A series of actuarial games, played on students' tablets or smartphones, introduce both empirical probability and the idea of expected value, while saving significant time over non-digital alternatives. (Received September 16, 2014)

1106-P1-2849 **Elizabeth A Miller*** (elizmiller@math.osu.edu). *Online Workshops for Calculus Students using the Articulate Mobile Player App.*

The Ohio State Mathematics and Statistics Learning Center has been supporting OSU's thousands of calculus students with workshops for many years. The workshops give students another opportunity to understand some of the most difficult topics in the first year calculus courses. Traditionally, these workshops have been taught in-person using a Smart Board and group work. Now, students are asking for anytime, anywhere assistance. We are responding by developing online workshops. In order to keep the "work" aspect of the workshops in place, we have developed the workshops using Articulate Storyline. These workshops include short videos, quizzes with instantaneous feedback, and problems for students to try with video solutions. The workshops can be completed online using a web-broswer or downloaded to the iPad with Articulate Mobile Player app. (Received September 16, 2014)

The Times They Are a Changin': Successful Innovations in Developmental Mathematics

1106-P5-96 **Pangyen Ben Weng*** (pangyen.weng@metrostate.edu), 700 E 7th St., St. Paul, MN 55106. *Developmental Math: Forward Thinking and Backward Designed.* Preliminary report.

Backward design is a method of designing educational curriculum by setting goals before choosing instructional methods and forms of assessment. One of the challenges for developmental math is that there are too many topics to cover within a short period of time. The author argues that a successful developmental math course should be backward designed to promote student mastery of a well-targeted set of topics and skills, and to help students build a sustainable and effective learning practice. The author presents a course he created using the concept, and demonstrates its effectiveness by examining student retention rate in the course and passing rate in the subsequent courses. (Received July 15, 2014)

1106-P5-169 **Luke Smith*** (lsmith4@aum.edu), School of Education, PO Box 244023, Montgomery, AL 36124. *Using Reform mathematics pedagogy in developmental mathematics courses to improve student success with application problems.*

Postsecondary remedial mathematics courses possess relatively low pass rates compared to other courses and have acquired the reputation as "gatekeepers" for college success. This quasi-experimental study examined the effect on student achievement that resulted from teaching postsecondary remedial mathematics students according to the pedagogical practices advocated by reform mathematics organizations (such as the National Council of Teachers of Mathematics) versus students who were taught through traditional didactic lecture. Student achievement was measured in terms of pass rates, procedural ability, application ability, and performance on the comprehensive departmental final exam. Statistical analysis controlled for variables in which the two groups significantly differed and found that students who received instruction according to reform pedagogy demonstrated significantly higher application ability than students who received traditional didactic lecture instruction ($p < 0.05$). Further, the gains in application ability did not come at the expense of pass rates or procedural ability. (Received August 04, 2014)

1106-P5-360 **Victor I Piercey*** (piercev1@ferris.edu), Department of Mathematics, 820 Campus Drive, ASC 2021, Big Rapids, MI 49307. *An Inquiry-Based Approach to Using and Manipulating Formulas.* Preliminary report.

A typical problem in both developmental and gateway courses is "Solve the formula for the specified variable." Students often struggle with these problems, typically because they are either overwhelmed by all of the variables or don't make connections between the algebra and arithmetic. In this talk, I will share an inquiry-based module designed to help developmental students make the connection between algebra and arithmetic and use this connection to solve problems. I will present data demonstrating the positive impact on student success, especially as it concerns the breadth of problems that students can solve at the end of the module. In addition, I will present data concerning the impact on math anxiety and beliefs. (Received August 25, 2014)

1106-P5-441 **Kimberly J Presser*** (kjpres@ship.edu), Shippensburg University, Department of Mathematics, MCT 274, Shippensburg, PA 17257. *Eliminating Barriers and Establishing Connections: Practices Outside of the Classroom to Encourage Successful Mathematics Remediation.* Preliminary report.

Shippensburg University has had Developmental Mathematics as an official part of the curriculum since 2003. The initial years of our program were focused internally on what the classroom would entail and how this curriculum prepared students for success in their college-level mathematics classroom. More recently, we have focused on external concerns related to student success such as placement procedures, non-classroom opportunities for remediation, intrusive advising practices, student engagement activities and connecting students with their college-level mathematics class. This talk would describe these procedures and the impact we have seen in student success because of these efforts. We will also discuss how challenges and pressures we have faced related to these efforts and plans for the future. (Received August 28, 2014)

1106-P5-549 **G. Arora**, **A. Klimas** and **V. L. Kocic***, Xavier University of Louisiana, New Orleans, LA 70125, and **D. Stutson** and **S. Unnithan**. *Comprehensive Reform of Developmental Mathematics at Xavier University of Louisiana.*

The reorganization and consolidation of the developmental mathematics course *MATH 0990D – Preparation for College Math*, has been one of the highest priorities of the Mathematics Department at Xavier University of Louisiana in the past three years. Low passing rate (51% at the end of fall 2011 semester) was a major concern for both the department and the University. During the spring of 2012 an ad-hoc committee, developed a comprehensive plan (approved by the department and the administration) for reorganization of the course. The plan addressed several areas that needed intervention such as: restructuring and reorganizing the course, placement policy, development of new course materials, student support, selection of teachers, coordination of the course, development of assessment tools, etc. The plan was implemented for the first time in fall 2012. The passing rate at the end of both fall 2012 and fall 2013 semesters increased to 72%. The same success rate (72%) has been obtained in fall 2013. The whole process of reorganization was supported by the NSF grant *Critical Juncture, STEM Educational Innovations Driven by Holistic, Integrative Evaluation Systems (I-3)* (Award # 0963641). (Received September 02, 2014)

1106-P5-584 **Paula R Stickles*** (pstickles@millikin.edu). *The Implementation of Online Homework in Developmental Mathematics and Its Impact on Successive Courses.*

Online homework systems are being utilized in our developmental mathematics courses. In this session we look at how students in Intermediate Algebra are progressing in their next course after succeeding with an online homework system. We tracked students through their next course where they may or may not have graded homework (online or traditional). Data regarding the use of the online homework system, student success rates in successive courses, pitfalls to avoid, and feedback from students will be shared. (Received September 02, 2014)

1106-P5-609 **G Michael Guy*** (michael@gmichaelguy.com), 222-05 56th Ave, Department of Mathematics & Computer Science, Bayside, NY 10022. *Accelerating Developmental Mathematics by Contextualizing Prerequisites into a Single Course using Problem-Solving (for STEM, too!).*

Faculty representatives from two-year and four-year colleges at the City University of New York (CUNY) drafted Elementary Algebra Learning Objectives and an accompanying CUNY Elementary Algebra Final Exam required of all developmental mathematics students across CUNY. Building on this faculty-led work, Queensborough Community College strengthened its existing developmental mathematics reform and created a more effective pathway for students. At one point, the department had four developmental mathematics courses, but all courses have now been replaced by a single semester Elementary Algebra course. This course supports both STEM and non-STEM students. We discuss how we have contextualized former prerequisite courses into a single course with improved pedagogy including guided problem solving. We will share quasi-experimental analysis of several semesters' results, and suggest future directions for improvement. This is joint work with Karan Puri and Jonathan Cornick. (Received September 03, 2014)

1106-P5-772 **Kenneth R. Bradfield*** (bradfi17@msu.edu), Michigan State University, Erickson Hall, 620 Farm Lane Rd. Room 118J, East Lansing, MI 48823, and **Raven McCrory**, **Steve Wolf**, **Beth Herbel-Eisenmann**, **Durrell Jones** and **Kristen Bieda**. *Creating a Cognitively Demanding Environment for Developmental Mathematics Student Learning.*

Across the country, post-secondary institutions design courses to meet the needs of students that are underprepared for their mainstream sequence of mathematics courses. Although these courses may have innovative methods of delivery, they continue to lack in teacher professional development and cognitively-demanding curriculum. This session will discuss an NSF-funded research project that facilitates students' mathematical development in a non-credit-bearing developmental mathematics course, in concert with providing prospective mathematics teachers an opportunity to learn to teach for mathematical proficiency. The project team developed a developmental mathematics curriculum that attends to conceptual development, strategic competence, and adaptive reasoning (Kilpatrick, Swafford, and Findell, 2001). Quantitative data from pre- and post- measures indicate the developmental math students initially started behind their peers in comparable sections of the course, but caught up by the end of the semester. More importantly, students in the intervention experienced more success than their peers in future mathematics courses. Qualitative data from interviews sheds light on features of the intervention that developmental math students found useful for their mathematical futures. (Received September 06, 2014)

1106-P5-846 **Don B. Small*** (don.small@ymail.com), 28 Pine Street, Cornwall on Hudson, NY 12520. *A Contemporary Approach to Intermediate Algebra.*

A Contemporary Approach to Intermediate Algebra

A contemporary approach to intermediate algebra focuses on two major goals (1) developing problem-solving skills and (2) developing students to become effective learners. The primary medium for addressing these goals is to establish a problem solving process to solve realistic word problems and to emphasize "learning how to learn" mathematics. Homework exercises are presented in word problem format. Strong emphasis is placed on modeling word problems, interpreting solutions, interpreting charts and graphs, and questioning. The course is designed to prepare students for college algebra as well as for the mathematics students' encounter in the social and biological sciences. The objective is to prepare students to integrate mathematics into their other courses and to engage them in mathematics that is critical to their being an informed citizen, not to force them into a calculus track. The recommended pedagogy is to "flip" the traditional lecture-homework pattern so that encountering and studying new material is central to homework assignments while class time is reserved for questioning, small group activities, and student presentations. (Received September 07, 2014)

1106-P5-882 **Nathan Wakefield*** (nathan.wakefield@unl.edu), Lincoln, NE 68588. *Improving Students Success in First Year Mathematics Courses at the University of Nebraska.*

Over the past few years, the Department of Mathematics at the University of Nebraska–Lincoln has taken significant steps to improve student success in introductory mathematics courses. Introductory mathematics courses are taught primarily by graduate students using an active learning method. Common lesson plans and worksheets have been developed and the courses are supervised to ensure continuity across sections. Over the past year, the department experimented by placing undergraduate learning assistants in the classrooms to help facilitate student learning, especially during those portions of class time devoted to group work. Further, the department has developed a graduate-level pedagogy course for first-time instructors. Implementing these reforms has posed some interesting challenges and some significant rewards. The ultimate goal is to improve student success without lowering standards. Preliminary results will be presented. (Received September 08, 2014)

1106-P5-919 **Joan E Brown*** (joan.brown@enmu.edu), ENMU, 1500 S. Ave K, Station 18, Portales, NM 88130, and **Tom R Brown** (tom.brown@enmu.edu), ENMU, 1500 S. Ave. K, Station18, Portales, NM 88130. *A Shorter Math Pipeline: Redesign and Assessment.*

ENMU has redesigned its entire developmental math offerings in an effort to shorten the number of classes students must complete to finish their math requirements.Learn about the assessment performed each semester and find out how this redesign has impacted student retention.

Redesign includes making the content relevant, shortening the math pipeline, adding support classes or labs, using technology, and backwards designing the prerequisite courses. Each semester we assess how well our students have done in each course, how well they have done in the subsequent course (retention) and adjust based on the assessment. (Received September 08, 2014)

1106-P5-1249 **Jan Orton Case*** (jcase@jsu.edu), JSU MCIS Department, 700 Pelham Road North, Jacksonville, AL 36265. *A Personalized Learning Approach to Developmental Mathematics.*

Seeking to improve the success rate of our developmental mathematics program, Jacksonville State University investigated learning materials developed by the National Repository of Online Courses (NROC) in 2011. NROC is a non-profit open educational resource project of The Monterey Institute of Technology and Education. The materials consist of videos, practice problems, assessment and an ebook, all of which are provided at no cost to the students. An institutional membership fee allows integration with the university's learning management system. JSU conducted a study of the materials when used in three different classroom contexts: (1) as optional, supplementary lessons, (2) as graded homework, and (3) in a flipped classroom environment. In each, the frequency of use of the materials correlated positively with higher test scores. Encouraged by these results, JSU is in a yearlong process of creating a personalized learning approach for all of our developmental mathematics courses. Partners in creating the new model include administrators, faculty, the mathematics curriculum committee, and existing university student support organizations. This paper summarizes the changes made and the lessons learned.

Find more information at: http://nrocmath.org/ and http://edready.org/. (Received September 11, 2014)

1106-P5-2554 **Van Herd*** (herd@austin.utexas.edu), College of Undergraduate Studies, University of Texas at Austin, Austin, TX 78712. *Implementing NCBO (Non-Credit Bearing Option) Bridge Mathematics Courses in the Research University: Lessons Learned in a Tier-1 Setting.*

Research has documented that student populations who have been identified as academically at risk enjoy much higher success rates in completing a research university mathematics sequence if they are placed in regular credit-bearing mathematics courses early, as opposed to deflecting those populations into developmental mathematics courses. Enrolling at-risk populations in the standard mathematics sequence can be can be achieved successfully with co-requisite NCBO support, the subject of this presentation.

In many states, such as Texas, state Tier 1 research universities are under unique mandate to accommodate these student populations and must develop equally unique pedagogical and curricular strategies. Under these mandates, such courses must be taught by regular university faculty and must not rely on outsourcing to community colleges.

This session presents lessons learned from the author's experience in developing and teaching such a bridge co-requisite NCBO at the University of Texas at Austin, and presents a blueprint for other research universities who may wish to implement such a programme. In addition, curriculum samples from the author will be made available, from which examples will be drawn during the presentation for use in replication sites. (Received September 16, 2014)

1106-P5-2681 **Taras Gula** (tgula@georgebrown.ca), Room 601, 51 Dockside Drive, George Brown College, Toronto, Ontario M5T 2T9, Canada, **Carolyn Hoessler** (carolyn.hoessler@usask.ca), Room 50 Murray Building, University of Saskatchewan, Saskatoon, Sask. , Canada, and **Wes Maciejewski*** (wes@math.ubc.ca), 1984 Mathematics Road, The University of British Columbia, Vancouver, BC V6T 1Z2, Canada. *Seeking Mathematics Success for College Students: A Randomized Field Trial of an Adapted Approach.*

Under-preparedness in basic mathematics is rampant among Canadian college students. In an effort to characterize this problem, a series of studies (the College Math Project) has determined that one-third of all college students in the province of Ontario are at risk of not completing their programs because of low ability in basic mathematics. This presentation reports the results of a control group trial of an approach to teaching developmental mathematics intended to remedy the under-preparedness problem. This approach has been adapted from a Canadian elementary school curriculum, JUMP Math. The instructional approach centres around explicit instruction and tightly-scaffolded lessons that gradually increase in difficulty and depth. Overall, the adapted JUMP Math approach produced favourable results, but not without further questions being raised. (Received September 16, 2014)

1106-P5-2697 **Hiro Yamada*** (yamada@carnegiefoundation.org), 51 Vista Lane, Stanford, CA 94305, and **Chris Thorn**. *Assessing the effectiveness of the Carnegie Pathways: A multilevel propensity score approach.*

The Carnegie Community College Pathways initiatives, Statway and Quantway, have been developed to promote students' progress through their mathematics requirements - both developmental and college level. Descriptive results for the Pathways' demonstrate extraordinary effectiveness in community colleges. For example, Statway has tripled the success rate for students in half the time to achieve college math credit. However, some might question whether selection bias exists, that is, whether the kinds of students enrolled in Statway have led to more positive outcomes than would otherwise be seen. In this study we used a multilevel propensity score matching technique to formulate a comparison group against which we could evaluate the effectiveness of Statway. Propensity score matching results are consistent with earlier descriptive findings. They replicate over two different cohorts and hold up for different gender and race/ethnicity groups as well as different math placement levels. Also, it is plausible that Statway's effects persist in the following year in terms of accumulated college credits earned. Discussion will be made regarding data use for priority setting for improvement. Similar analyses of Quantway effectiveness are underway. (Received September 16, 2014)

1106-P5-2701 **Ann Edwards*** (edwards@carnegiefoundation.org), 51 Vista Lane, Stanford, CA 94305, and **Cinnamon Hillyard**. *The Carnegie Pathways: Innovating for Student Success in Statway and Quantway.*

Launched in classrooms in Fall 2011, the Carnegie Community College Pathways, Statway and Quantway, have dramatically increased student success rates in developmental math, tripling the student success rate in one-half the time. After three years of implementation in nearly 50 community colleges and universities, in 15 states, the Pathways have reached over 9,000 students. In contrast to other reform efforts, Pathway colleges are part of a Networked Improvement Community where faculty work together with other practitioners and researchers to identify barriers to their students' mathematical success and design and test instructional and curricular innovations to overcome those barriers. In this talk, we describe the innovations that have contributed to the Pathways' success–relevant and challenging college-level curriculum, instructional routines promoting student motivation and engagement, and pedagogy supporting collaborative learning through productive struggle–and share what we have learned about how to help developmental mathematics students persist and achieve. We will also discuss how Pathways faculty are supported to innovate and succeed in their classrooms and share what we have learned about robust faculty development in community college developmental mathematics. (Received September 16, 2014)

1106-P5-2738 **Gregory D. Foley*** (foleyg@ohio.edu), Ohio University, Athens, OH 45701-2979. *College Quantitative Reasoning: An Innovative Yearlong Course in Mathematics, Statistics, and Modeling.* Preliminary report.

College Quantitative Reasoning (CQR) is a yearlong course for college freshmen who have completed Algebra I, Geometry, and perhaps other mathematics courses in high school yet have placed into developmental mathematics. The CQR course develops mathematical proficiency, statistical capability, and quantitative literacy. Students use prior, but not fully internalized, mathematics in the service on new ideas. The first 10-week unit on Number and Quantity explicitly teaches problem-solving strategies while developing skills, concepts, and applications related to quantities, fractions, decimals, percent, recursion, financial literacy, proportional reasoning, averages, indices, codes, logarithms, and matrices. Following this developmental unit are 10-week units on probability and statistics and on modeling with algebra, functions, and trigonometry. The CQR course balances reasoning and sense making with communication and in-context problem solving. Motivating questions and challenging investigations are the heart of the course. These rich tasks engage students and leverage mathematical action technologies. They have been tested in technology-intensive classroom environments focused on language, thinking, and learning. (Received September 16, 2014)

1106-P5-2769 **Rodica Cazacu*** (rodica.cazacu@gcsu.edu), Georgia College, Department of Mathematics, CBX 17, Milledgeville, GA 31061, and **Marcela Chiorescu**. *A Personalized Solution for Increased Student Success.* Preliminary report.

An important component of undergraduate education is the understanding of basic mathematics. To help students enhance their basic mathematical knowledge necessary for their academic success, Georgia College has begun offering a redesigned College Algebra course based on the latest technology and learner-centered pedagogy. This presentation will give an overview of how the redesigned course was implemented and the results we got for the first three years, as well as the impact it had on retention and students' performance in other mathematics courses following this one. (Received September 16, 2014)

1106-P5-2870 **Michael George*** (mgeorge@bmcc.cuny.edu), 199 Chambers St, New YOrk, NY 10007, **Annie Y Han** (yhan@bmcc.cuny.edu), 199 Chambers St., New York, NY 10007, and **Yevgeniy Milman** (ymilman@bmcc.cuny.edu), 199 Chambers St., New York, NY 10007. *The Way to Quantitative Literacy for College Developmental Mathematics Students.*

The problem of perennially low passing rates in developmental mathematics has plagued community colleges with years. Efforts to solve this problem have rarely sought to question the fundamental character of the curriculum itself. Quantitative Literacy offers non-STEM students an alternative path to college level mathematics that may be more suited to their mathematical needs than Elementary Algebra. This paper describes the implementation of Quantitative Literacy at a large inner-city Community College. Students enrolled in the 17 sections of Quantitative Literacy were compared to a matched sample of students from traditional elementary algebra. The students enrolled in Quantitative Literacy in the Spring of 2013 were 175% more likely to have passed a credit-bearing mathematics course one year later, indicating that QL represents a valuable alternative for non-STEM college students placed into algebra level remediation. (Received September 16, 2014)

Trends in Undergraduate Mathematical Biology Education

1106-Q1-6 **E Cabral Balreira*** (ebalreir@trinity.edu), One Trinity Place, San Antonio, TX 78212. *An Oracle Method to Rank a Tournament from NFL Teams to Green Anoles.* Preliminary report.

We introduce several models for ranking teams in a league and discuss an original model developed by the author called the Oracle method. Using Linear Algebra and Network Analysis, we will illustrate how this model works to rank teams in the NFL and show this method to predict game outcomes better than other well-known methods. As an application, we will see how ranking methods can be used in mathematical biology to determine hierarch in the population of Green Anoles (*Anolis carolinensis*) as well as discovering which traits contribute to their hierarchy. (Received April 19, 2014)

1106-Q1-90 **Diana S Cheng*** (dcheng@towson.edu), 8000 York Road, Towson, MD 21286, and **David Thompson**. *An Animal Population Simulation and Mathematical Modeling Activity for Secondary Mathematics Majors.*

We demonstrate how a biology-based, mathematical modeling experiment can be conducted in undergraduate mathematics courses for secondary education majors (pre-service teachers). The experiment is based on animal species population data gathered from the World Wildlife Foundation and the International Union for Conservation of Nature. It helps students learn about the threatened level classifications of species based on percentages of population reduction, and involves students' collecting data and analyzing linear, quadratic and exponential regressions. The Common Core State Standards for Mathematics – both the Standards for Mathematical Practice and Content Standards – which this experiment can address will be described. (Received July 07, 2014)

1106-Q1-802 **G. Brock Williams*** (brock.williams@ttu.edu), Dept of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409-1042, and **John Calhoun**, **Whitney Green**, **Levi Johnson** and **Jessica Spott**. *Involving Undergraduates in Biomath Research Using High Performance GPU Computing.*

We will describe the new LAZARUS high performance GPU computing lab and particularly the role of undergraduates in solving biomath problems in the lab. The heavy use of social media has also helped to both attract students to work on the project and to explain what research is really like. (Received September 07, 2014)

1106-Q1-1399 **Elizabeth C. Davis-Berg** and **Daniel R. Jordan*** (djordan@colum.edu), Columbia College Chicago, Department of Science and Mathematics, 600 S. Michigan Ave., Chicago, IL 60605. *Interactive Mathematica-based biodiversity exercise enhances student understanding.*

We created interactive exercises that students can use to explore biological concepts. These active learning experiences allow students to enter data and modify parameters without knowing how to use *Mathematica*. Using these exercises enhances student understanding by allowing them to focus on the biological concepts and visualize the data and calculations without the tedium of hand computation.

This presentation will highlight an interactive version of a biodiversity lab that explores Simpson's Diversity Index. Students are walked through the calculations with a small data set and are then asked to analyze a larger data set. This larger data set is presented as a set of interactive graphs so that they can explore and manipulate the data in order to answer questions. It also allows students to visually experience the concepts without having to complete all the calculations themselves. For our non-major audience, this means that we can have a more sophisticated discussion without getting stuck on the calculations. We will present the exercises as well as the assessment results and our future directions. (Received September 12, 2014)

1106-Q1-2431 **Lester F Caudill***, University of Richmond, Department of Mathematics & Computer Science, Richmond, VA. *IQS 2.0: A Modularized Integrated Math and Science Course.*

For the past several years, the University of Richmond has offered an Integrated Quantitative Science (IQS) course, integrating introductory courses in five math and science disciplines, to first-year students. Recently, the second generation, IQS 2.0, has been successfully implemented. We will describe the significant changes to the course, focusing on ways to make the course more modular and exportable. (Received September 16, 2014)

1106-Q1-2491 **Pam Ryan*** (pjryan@truman.edu), Truman State University, Department of Mathematics, 100 E Normal St, Kirksville, MO 63501. *The Mathematical Biology research program and minor at Truman State University.*

Truman State University has received two UBM (Undergraduate Biology and Mathematics) grants from the NSF in the past ten years. The grant funds were used to build an interdisciplinary mathematical biology research program and a mathematical biology minor. I will talk about the results of the program, the mathematical biology minor that was created as a result, and a few simple classroom activities for calculus classes motivated by biology. (Received September 16, 2014)

1106-Q1-2505 **Shantia Yarahmadian*** (syarahmadian@math.msstate.edu), **Hadi Khani** and **Eda Asili**. *A Mathematical Model for Alzheimer Disease and it's Treatment Based on the Metal Ions Hypothesis.*

The aggregation of amyloid-beta by self-assembly into oligomers is a central event in Alzheimer's disease. In this work, we propose a mathematical model as a set of coupled kinetic equations that governs the self-assembly of amyloid-beta filaments in the presence of transition-metal ions. Metal ions have been hypothesized as an important factor in the pathogenesis of AD. There is a considerable literature supporting the impact of metal ions such as copper (Cu), zinc (Zn) and iron (Fe) in many critical aspects of AD and other neurodegenerative diseases. Our study includes Cu and Zn as main transition-metal ions, where their coordination to A-beta regulates the aggregation process in vivo. Metal ions mostly affect the nucleation phase and change both the structure and the charge of A-beta. Our model describes the general features of the kinetics of fragmenting filamentous structures. (Received September 16, 2014)

1106-Q1-2788 **Timothy D Comar*** (tcomar@ben.edu), Department of Mathematics, Benedictine University, 5700 College RD, Lisle, IL 60091. *Computer Laboratory Activities for Biocalculus Courses.*

The biocalculus courses at Benedictine University use a threefold approach integrating mathematics, biology, and the use of computational software to investigate biologically oriented problems. The courses now integrate the computer laboratory component with the lecture component rather than have separate laboratory courses. The courses meet in computer laboratory classrooms several times a week and provide a more flexible format for incorporating the computational activities. We demonstrate several activities using either Maple or Excel to explore biological problems and the mathematics needed to address biological problems. We also discuss how these projects are used in the courses, how they can enhance the learning process, and how they can be adapted to other applications. (Received September 16, 2014)

USE Math: Undergraduate Sustainability Experiences in the Mathematics Classroom

1106-Q5-464 **William C Bauldry*** (bauldrywc@appstate.edu), Dept of Math Sciences, Appalachian State University, 121 Bodenheimer Dr, Boone, NC 28608. *Introducing Students to Prioritizing Sustainability Options by Using the Analytic Hierarchy Process.* Preliminary report.

We introduce students to the Analytic Hierarchy Process (AHP), a technique from Operations Research that can be used to select, prioritize, and rank options. A student project will be given along with sample modules presenting AHP for students with different levels and backgrounds. (Received August 29, 2014)

1106-Q5-1330 **Grant Lee Innerst*** (gi7584@ship.edu). *Sustainability on the Half Shell: Modeling Oyster Populations.*

Population modeling, often addressed in courses ranging from College Algebra to Differential Equations is not often associated with sustainability. On the eastern shore of Virginia, oyster beds are being created to help prevent shoreline erosion. The growth of these oyster populations is of great interest to land owners, environmentalists and local businesses. In this talk, we will discuss population models of the Eastern Oyster based on data from Chincoteague Bay, Virginia region and how these models can be scaled for use in multiple classroom settings. (Received September 12, 2014)

1106-Q5-1405 **Amanda I Beecher*** (abeecher@ramapo.edu), TAS, 505 Ramapo Valley Rd, Mahwah, NJ 07430. *Measuring Sustainability as a First Year Seminar.*

I taught a First Year Seminar called "Measuring Sustainability" at Ramapo College of New Jersey. I used group projects, data collection, data analysis, and peer-reviewed writing assignments exploring sustainability topics to help students develop and refine academic skills required for success at Ramapo. We introduced students to sustainability initiatives at Ramapo from a quantitative perspective to measure the true impact of our choices. This course began developing at the USE Math MAA PREP workshop in Shippensburg University in summer 2013. (Received September 12, 2014)

1106-Q5-1787 **Stephanie Kajpust*** (stephanie.kajpust@finlandia.edu). *Bringing Biodiversity into the Quantitative Literacy Classroom.*

A good way to learn quantitative literacy is through the theme of environment, sustainability, and biodiversity. In this talk we will discuss how the local environment can be incorporated into the classroom through estimation, measurement, and analysis of biodiversity and the accompanying data. An example lesson and classroom results will be presented. (Received September 15, 2014)

1106-Q5-2051 **Monika Kiss*** (monika.kiss@saintleo.edu), 7543 Kickliter Lane, Land O Lakes, FL 34637. *Group Projects on Sustainability in College Algebra.*

In this presentation, we shall discuss some examples that were implemented in a college algebra class on sustainability. We will look at how the problems were selected, what worked and what could be improved in the future. (Received September 15, 2014)

1106-Q5-2201 **Rikki Wagstrom*** (rikki.wagstrom@metrostate.edu), Metropolitan State University, 700 East 7th Street, Saint Paul, MN 55106, and **Jodin Morey** (we9180ef@metrostate.edu), Metropolitan State University, 700 East 7th Street, Saint Paul, MN 55106. *The Monarch and the Milkweed: An Exploration for Algebra Courses.*

In this presentation, a two-part curriculum appropriate for college algebra and pre-calculus courses will be discussed. The curriculum explores the topic of declining milkweed populations in Midwestern states and the potential implications for monarch butterflies. Milkweed is the primary food source for monarch larva and is therefore essential to the reproductive success of the species. The curriculum incorporates a range of quantitative literacy and algebraic skills: calculating and interpreting percent changes, working with units, interpreting densities, understanding and modeling exponential growth and decay, and making projections. The curriculum was piloted and evaluated in two sections of algebra courses during fall 2014. Student responses from the evaluations will be highlighted. (Received September 16, 2014)

1106-Q5-2203 **Jodin Morey*** (we9180ef@metrostate.edu), Metropolitan State University, 700 East 7th Street, Saint Paul, MN 55106, and **Rikki Wagstrom** (rikki.wagstrom@metrostate.edu), Metropolitan State University, 700 East 7th Street, Saint Paul, MN 55106. *Comparing Greenhouse Gas Emissions from Automobile Fuels: An Exploration for Algebra Courses.*

In this presentation, curriculum developed by an undergraduate math education major and a math faculty mentor will be discussed. The curriculum, appropriate for college algebra and pre-calculus courses, explores the environmental impact of the most common liquid fuels we use in our automobiles. In particular, the curriculum guides students to calculate and evaluate the greenhouse gas emissions of conventional gasoline, diesel, different ethanol blends, and biodiesel. The curriculum incorporates a range of quantitative literacy and algebraic skills: calculating and interpreting percent changes, working with units and unit conversion, calculating rates of change, and deriving and using multivariable functions. This curriculum was piloted and evaluated in three sections of algebra courses during fall 2014. Student responses from the evaluations will be highlighted. The benefits and challenges of this type of experience for advanced math education majors will also be discussed. (Received September 16, 2014)

1106-Q5-2326 **Kris H. Green*** (kgreen@sjfc.edu), 3690 East Ave, Rochester, NY 14607. *Planning Ahead: Database restructuring to support research.*

While attending the USE Math PREP session in the summer of 2014, I became involved in a project to restructure an existing database. The goal was to make it more usable for students and researchers to carry out investigations. In this talk, I will provide some background on the database, and then discuss the process of restructuring it. Along the way, we will look at this from the perspective of preparing our students – both math majors and general education – to tackle similar tasks and how to avoid the need for restructuring through careful planning. (Received September 16, 2014)

1106-Q5-2552 **Maria L Hernandez*** (hernandez@ncssm.edu), 1219 Broad Street, Durham, NC 27707. *Estimating Ocean Populations and Biodiversity in the Bay: An Algebra Activity.*

In this session, we will share an activity focused on estimating populations of sea life in Chincoteague Bay, VA. Considering data collected at Wallops Island Field Station, we ask students to estimate the populations of sea creatures in various trophic levels. Then they use Simpson's Diversity Index to measure diversity in the bay. Making sense of the index calculation, leads us to a conversation about the behavior of various power functions. This interdisciplinary activity is appropriate for Algebra students. (Received September 16, 2014)

1106-Q5-2582 **Janine M Lloyd*** (jlloyd@massbay.edu), 50 Oakland St, Wellesley, MA 02481. *Sustainability Projects in the Quantitative Reasoning Classroom.*

Sustainability is a natural topic to consider when teaching Quantitative Reasoning. This session will present several projects used in a Quantitative Reasoning class in a Community College setting. The topics cover linear regression through an examination of the Greenhouse effect, unit analysis by putting recycling into perspective and modeling through studying product redesign. (Received September 16, 2014)

1106-Q5-2607 **Sharareh Nikbakht*** (nikbakhts@appstate.edu), Department of Mathematical Sciences, ASU Box, 32092, Boone, NC 28608, and **Yelena Meadows** (meadowsy@faculty.uiu.edu), Bishop Walsh High School, Cumberland, MD 21502. *salt marshes math lab.*

Teaching mathematics concepts in developmental math course is challenging as students may not see the relevance of what they learn in the real world. Providing examples on how math is used to solve problems in different disciplines can generate interest and result in an improved learning. In this presentation, the authors will discuss a real world example where students used the collected data on Fiddler Crab at the Wallops Island Salt Marshes to investigate some math concepts. The sample activity will provide students an opportunity to gain experience with calculating volume, conducting basic statistics, and learning about unit conversion. The activity helps students improve their problem solving while learning about several mathematical concepts (Received September 16, 2014)

Using Flipping Pedagogy to Engage Students in Learning Mathematics

1106-R1-27 **Jenna Van Sickle*** (jvansickle@fontbonne.edu). *Adventures in flipping college algebra.*

This presentation will give an example of a flipped lesson, discuss strengths, weaknesses, problems, and solutions I have experienced flipping the classroom in my college algebra course. I used screencasting technology to flip the course. Students watched short lecture videos outside the classroom, and class time was devoted to problem solving. I will discuss strategies and technology that have helped make the transition to a flipped classroom easier as well as difficulties I have experienced with the technology and the format. I will also discuss students concerns and feedback regarding the flipped classroom, as well as a statistical analysis of their final exams and course evaluations. I will have a discussion of how this strategy can be improved for the future, what I would do differently for future courses, and how I used a flipped model to transition to a blended and a fully online course. (Received April 30, 2014)

1106-R1-94 **Pangyen Ben Weng*** (pangyen.weng@metrostate.edu), 700 E 7th St., St. Paul, MN 55106. *Flipping the Developmental Math Classroom: Self-Pacing is Key.*

Students in the a developmental math class rarely have the same level of readiness or ability: while stronger students are often uninspired or under-challenged, weaker students would feel rushed and intimidated as the class progresses. Flipped instruction with self-paced learning can solve this problem. In this presentation, the author discusses how to effectively use flipped instruction in the developmental math classroom and demonstrates the design he uses at Metropolitan State University. He also presents successful learning outcomes and positive student feedback, and offers his reflection on how to improve in the future. (Received August 29, 2014)

1106-R1-214 **Erick Hofacker*** (erick.b.hofacker@uwrf.edu), 214C North Hall, River Falls, WI 54022.
Flipping the Classroom Routine in Statistics.

The course is designed for students to complete 19 different modules, which all have similar formats. The delivery of the course involves the use of screencasts, created by the professor, that showcase concepts, terminology, procedures, and technological demonstrations. Once students have viewed the videos, the learning management system unlocks a short prep quiz that they complete before class.

At the start of class, students are asked to present information from the videos and define terminology at the board. That information is typically left on the board through the hour and is used to jump start a large group discussion that looks at where statistical questions would be posed in real-life situations. Students are then broken into smaller teams (3-6) and typically work on a statistical task. Student reasoning & sense making of the task is collected through taking pictures on camera phones and is presented to their peers. Students then move to an interactive activity involving some form of technology to assist with representation and conceptual understanding. The module concludes with students working on application problems delivered through MAA WeBWork. As students work they are encouraged to work in teams and share information and assistance across teams. (Received August 11, 2014)

1106-R1-283 **Matthew J. Peeples*** (peeples@naps.edu), 440 Meyerkord Ave., Newport, RI 02841.
Flipping the class using Google Documents at the Naval Academy Preparatory School.
Preliminary report.

At the Naval Academy Preparatory School (NAPS), students come from across the United States with a very diverse range of abilities. A flipped classroom offers a means by which a wide range of students can be reached within each classroom with a differentiated approach, rather than a traditional, one-size-fits-all lecture approach. An innovation that I introduced this year involved the use of video lessons uploaded to You Tube and embedded in forms I created using Google Docs as a means to follow up each lesson. When I started using the flipped approach, I was initially optimistic about how well I would be able to implement it. However, I found that preparation and execution were both more time consuming and difficult than I had envisioned. In this presentation, I detail how I dealt with the problems of creating video lessons along with documentation, follow up in class and adjusting syllabus assignments to fit the time requirements for each class period. I also show that despite the greater amount of time and effort than what I had initially anticipated, I found the method to be effective at allowing me to spend more time working with individual students in a way I was unable to when I spent most of my class time lecturing. (Received August 19, 2014)

1106-R1-524 **Dr. Jason A. Willis*** (jwillis@gardner-webb.edu), Gardner-Webb Campus P.O. Box 7261, Boiling Springs, NC 28017, and **Dr. George Olson**, **Dr. Deborah Crocker** and **Dr. Tracy Goodson-Espy**. *Perspectives of Flipping an Undergraduate Precalculus Class.*

The flipped classroom model of instruction has become an alternative to traditional, lecture-based instruction. An experiment with the flipped classroom and a survey of the students involved revealed some interesting information about the instructional model. The experiment was designed with two undergraduate Precalculus classes in a small, private college in the southeastern United States. Since all flipped classrooms are not the same, we discussed specifically how the flipped classroom was designed and how the control and experimental classes were compared. A student survey was used to gather the perceptions and attitudes toward the flipped classroom and field notes were analyzed to gain the instructor's perspective. (Received September 01, 2014)

1106-R1-532 **Joseph Phillip Brennan*** (jbrennan@binghamton.edu), Binghamton, NY , and **Laura Anderson**. *SUNY Binghamton's Hybrid Approach to Teaching Calculus.*

At Binghamton, Calculus 1 is taught to over 1,000 students each fall. The satisfaction and performance of students in this course is often poor. We had hoped to improve student success by changing how we teach and not by lowering our standards.

In the fall of 2013 the Binghamton University Department of Mathematical Sciences undertook an experiment in flipped teaching with Calculus 1. We wanted to compare flipped and our traditional methods in several respects:

- Which method leads to better student performance in terms of computational ability? In terms of more in-depth problem-solving ability? conceptual understanding? performance in Calculus 2?

- Were the answers to the above questions different for students coming in with weaker math skills than the norm? Were they different for people seeing Calculus for the first time than for those with a high-school calculus course behind them?

Overall, our quantitative analysis found moderate benefits to flipping over traditional methods for all groups studied. Informally, while student opinion varied, instructors largely were quite positive, finding that their students were more engaged and that instructors were able to give students more individualized attention. (Received September 01, 2014)

1106-R1-585 **Craig Patrick McBride*** (mcbridec@uw.edu). *Flipping an Introductory Statistics Class: Students' Attitudes About and Success with the use of Online Tools.* Preliminary report.

The study determined the effectiveness of flipping a college level Introductory Statistics course. I wanted to assess the effectiveness of using online homework and quizzes by analyzing scores and students' attitudes. The sample consisted of (N=40) mostly Freshman and Sophomore students in a private college located in the Pacific Northwest. The class was flipped using Powerpoints to deliver lecture material. Students read the slides outside of class, so we could devote class time to answering some guided questions and working through examples of the techniques. This enabled me to use differentiated teaching and work with groups or students one-on-one answering questions and providing formative feedback. When necessary, Powerpoints were supplemented with applets, online resources, video lessons and tutorials. Additionally, I would use class time to present mini-lectures whenever the subject matter required it. Student attitudes were collected via online surveys, and their performance was compared to previous sections and concurrent sections taught traditionally. Midway through the term, students were asked to voluntarily do the rest of their homework and quizzes with MyStatLab. Nine of the students opted out, which enabled me to compare the test and quiz scores of the two groups. (Received September 02, 2014)

1106-R1-895 **Jenny G. Fuselier*** (jfuselie@highpoint.edu), 833 Montlieu Ave., Drawer 31, High Point, NC 27262, and **Laurie Zack** (lzack@highpoint.edu), **Adam Graham-Squire** (agrahams@highpoint.edu) and **Karen O'Hara** (kohara@highpoint.edu). *Flipping Freshman Mathematics: Discouraging Results and How to Adapt for the Future.* Preliminary report.

In the fall of 2013, we conducted an experiment comparing standard lecture and flipped methodologies in four freshman level math courses. No statistical difference was found in the test scores of the students, though qualitative data indicated potential problems with implementing flipped pedagogy. In particular, we found that a number of students had a negative opinion of the flipped model, and that attitudes toward math in general tended to decline, comparatively, for students in the flipped class. Based on these results, each instructor modified their methods in subsequent semesters. In this talk, we will focus on these adaptations, student responses, and strategies for improving students' willingness to take ownership of their learning. (Received September 08, 2014)

1106-R1-925 **Rebecca Swanson*** (swanson@mines.edu), Applied Mathematics & Statistics, Colorado School of Mines, 1500 Illinois St., Golden, CO 80301, **Deb Carney** (dcarney@mines.edu), Applied Mathematics & Statistics, Colorado School of Mines, 1500 Illinois St., Golden, CO 80401, and **Nic Ormes** (normes@math.du.edu), Department of Mathematics, University of Denver, Aspen Hall 715B, Denver, CO 80208. *A Team-Based Approach to a Partially Flipped Linear Algebra Class.* Preliminary report.

In this talk we will discuss our partially flipped introductory linear algebra course. We will provide motivation for our design and our process of implementation. Three faculty members worked collaboratively across two universities to develop videos and activities. Our preliminary results indicate that we were successful in increasing student exam performance and lowering DFW rates. Additionally, survey data indicates our students were generally positive about their flipped learning experience. (Received September 08, 2014)

1106-R1-944 **Brian J. Winkel*** (brianwinkel@simiode.org). *Application Driving Learning in Differential Equations.*

We discuss a flipping of the learning environment in which application comes before the introduction of the mathematics. In a differential equations course in which modeling is the driving force and technology is used throughout the learning process we demonstrate how a learning community at www.simiode.org supports such an approach. We call it SIMIODE - Systemic Initiative for Modeling Investigations and Opportunities with Differential Equations. We will give examples of such flipping. (Received September 09, 2014)

1106-R1-1027 **Jennifer E Clinkenbeard*** (jclinkenbeard@fullerton.edu) and **Cherie Ichinose** (cichinose@fullerton.edu). *Flipping College Algebra to Increase Student Engagement and Achievement.*

The flipped learning environment blends the innovation of online learning with student centered face-to-face instruction. In this session, we present a pilot study comparing a flipped college algebra class with a traditional lecture. The data were gathered in spring and summer of 2014. The model for the flipped class engages the student on three distinct occasions: online modular mini-lectures with embedded questions; a pre-assessment; and an in-person math lab discussion facilitated by the professor. Using a pre- and post-test method, we employ standardized assessments and rubrics in both course models to compare both academic and affective domains. Preliminary findings suggest that the passing rates for students in the flipped model were statistically higher than students in the traditional class ($t = 3.701$, $df = 650$, $p < .001$). In addition to comparing the grades of individual students in each classroom model on each major exam as well as their final course grade, we also consider the change in content mastery as demonstrated by the student via the Mathematics Diagnostic Testing Project; the change in reported mathematical beliefs via the 2012 Programme for International Student Assessment; and the comparison of responses with regard to the class setting. (Received September 09, 2014)

1106-R1-1186 **Cassie Williams***, willi5cl@jmu.edu, and **John (Zig) Siegfried**. *Effecting Student Learning Gains in Calculus I via the Flipped Classroom Model.* Preliminary report.

The flipped classroom has garnered attention in post-secondary mathematics in the past few years, but much of the research on this model has been on student perceptions rather than its effect on the attainment of learning goals. Instead of comparing to a "traditional" model, in this study we investigate student learning gains in two flipped sections of Calculus I. Specifically, we consider best practices in constructing videos and in-class activities, examine student learning gains on first encounter with new material via videos or activities, and explore what types of learning goals may be best suited to this kind of classroom structure. We will share preliminary qualitative data from our exploratory teaching experiment, including student artifacts, video analysis, and survey feedback. In addition, we will share aggregate exam data from the two classrooms, along with anecdotal evidence from three semesters of flipping. (Received September 11, 2014)

1106-R1-1288 **Diana White*** (diana.white@ucdenver.edu). *Using Preview Activities to Partially Flip an Undergraduate Abstract Algebra Course.*

In addition to teaching content, there are a variety of skills that a math major should learn. These include things like effectively communicating mathematics in written and oral form, learning to create and explore both examples and counterexamples, learning to ask good mathematical questions, and learning to see the "big picture" of the content in addition to learning and applying specific results. In this talk, we discuss how the author uses preview activities to partial invert a first course in abstract algebra. We discuss how these preview activities are implemented and how they connect to learning the aforementioned skills. (Received September 11, 2014)

1106-R1-1351 **Krista Maxson*** (kmaxson@shawnee.edu), 940 Second Street, Portsmouth, OH 45662. *Using the Flipped Classroom to offer Dual Enrollment courses.* Preliminary report.

Dual Enrollment provides high school students the opportunity to take college-credit bearing courses taught by college-approved high school teachers. This presentation will outline the process used to create four college-level mathematics courses in the flipped format for use in offering dual enrollment courses at local high schools. Eight faculty in the department of Mathematical Sciences at Shawnee State University worked with 20 high school teachers to create content and resources for college algebra, trigonometry, calculus and statistics. Fifteen of the high school teachers completed nine semester hours of graduate mathematics over the summer and are offering the courses at their high school mentored by faculty in the department. The report will highlight what worked as well as lessons learned. This effort was supported financially by a Straight-A-Fund (Ohio Department of Education) grant. (Received September 12, 2014)

1106-R1-1460 **Julia Rose Murphy*** (juliarosemurphy@gmail.com) and **Jen-Mei Chang**. *Experience a Flipped Learning Outcome through Flipped Learning in an Introductory Linear Algebra Class.* Preliminary report.

Flipped learning is gaining traction in K-12 for enhancing students' problem solving skills at an early age; however, there is relatively little large scale research showing its effectiveness in promoting better learning outcomes in higher education, especially in mathematics classes. In this study, we examined the data compiled from both quantitative and qualitative measures such as item scores on the common final and attitude survey results between a flipped and a traditional Introductory Linear Algebra class taught by two individual instructors at California State University, Long Beach in Fall 2013. Examination of the quality and depth of student responses from the common final exam showed that students in the flipped class produced more comprehensive and well-explained responses to the questions that required reasoning, creating examples, and more complex use of mathematical objects. Furthermore, students in the flipped class performed superiorly in the overall comprehension of the content with a 21% increase in the median final exam score. Overall, students felt more confident about their ability to learn mathematics independently and acquired many meta-skills that are useful in helping them succeed in other math classes after having gone through this flipped class. (Received September 13, 2014)

1106-R1-1905 **Larissa Schroeder*** (schroeder@hartford.edu), 200 Bloomfield Avenue, W. Hartford, CT 06117, and **Jean McGivney-Burelle** (burelle@hartford.edu) and **Fei Xue** (xue@hartford.edu). *Students' Perceptions of Flipped Calculus.*

In fall 2014, Flipping Calculus (NSF DUE 1245059) was implemented in all sections of Calculus I at the University of Hartford. To assess students' perceptions of this pedagogy we distributed a pre- and post-survey, which was adapted from the Student Assessment of their Learning Gains (SALG). In this session we will present and discuss general survey results. Further, we will examine any differences in student perceptions across course sections, major, gender, mathematics background, or other variables of interest. (Received September 15, 2014)

1106-R1-2240 **Adam M Glesser*** (aglesser@fullerton.edu). *Jay Leno and Abstract Algebra.* Preliminary report.

The goal of many lecturers is to present in a logical way, properly motivating the material with context, applications, and examples. Recent work in education research, however, shows that students watching dialogues that present common student misconceptions consistently perform better on post-tests than students watching a traditional lecture-style video with only correct information presented.

I recorded videos with two undergraduate students that show typical mistakes of a student taking a first course in group theory. The aim is to create temporary confusion, helping the viewer to develop an *intellectual need* for resolution. Faculty teaching an algebra sequence can choose which of these videos to assign to students in order to reduce the amount of time spent—often fruitlessly—covering these mistakes in lecture, freeing time for other activities. The videos are different from those produced by, say, Khan Academy, in that they are not meant to replace lecture, but rather to enhance it. Furthermore, the videos are short (generally under 10 minutes) so as to increase their modularity, and so as to not overburden the student.

This talk will discuss both the inherent value of the videos as well as the value to the faculty and students in their production. (Received September 16, 2014)

1106-R1-2293 **Charles Bergeron*** (chbergeron@gmail.com), Albany College of Pharmacy, and Health Sciences, 106 New Scotland Ave, Albany, NY 12208. *A flipped Differential Equations with no videos.* Preliminary report.

I am teaching a 3-credit introductory Differential Equations course with selected Linear Algebra topics to second-year Chemistry and Pharmacy students. This course features a focus on life science applications, the open-access textbook by Jiri Lebl, the open-access computer algebra system Maxima, standards-based grading, and a flipped style. Before class, students are expected to read a few pages, answer reading questions, and complete introductory exercises. Most in-class time is spent discussing student difficulties with these pre-class activities and working through more challenging exercises. A weekly help session is used to address follow-up questions. Answers to most exercises are not provided; students are expected to (i) plug their solution into the differential equation to ensure its validity and (ii) compare their answer with that obtained using Maxima. This talk will feature preliminary results from student assessment of these course features, as well as a discussion of the pros and cons of a "low-tech" flip not involving recorded videos or interactive modules. (Received September 16, 2014)

1106-R1-2296 **J.C. Price*** (jprice12@ggc.edu), 2252 Chateau Dr., Lawrenceville, GA 30043. *Flipping Calculus: A Paradigm Shift.* Preliminary report.

In this talk we will discuss our three semesters of experience with flipping a calculus class. In particular, we will review how Camtasia, YouTube, and Google have been utilized to create screencast lectures at www.youtube.com/user/drprice765. Our emphasis will be on our innovative instructional and classroom design, where students collaborate in small groups, along with two students working at a whiteboard, to solve problems. These solutions are then compared and contrasted to each other, and to the instructor's solution, in order to make light of common mistakes and serve as a platform to discuss related topics. The overall outcome to this design is an active learning environment that encourages students to openly discuss mathematics, form learning communities, compare and contrast ideas, and work together to solve problems. (Received September 16, 2014)

1106-R1-2374 **Perry Y.C. Lee*** (plee@kutztown.edu), Lytle Hall 267, Kutztown University of Pennsylvania, Kutztown, PA 19530, and **Padraig McLoughlin** (mcloughl@kutztown.edu), Lytle Hall 265, Kutztown, PA 19530. *A Comparison of Student-Learned Outcomes in Multi-Sections of 'Large' College Algebra Classrooms: A Preliminary Study.* Preliminary report.

For the past three semesters, one author implemented a method which uses both the Flipped and the IBL methods (or the F/IBL method) into his 'large' College Algebra classrooms for managing and engaging students both inside and outside the classroom setting.

During this past 2014 Fall semester, student-learned outcomes were assessed to determine the effectiveness of this F/IBL approach in his 'large' College Algebra classroom compared to multiple sections other 'large' College Algebra classrooms that were taught using the traditional lecture-style methods. In these large multi-section classrooms, student scores were collected by prescribing two assessments during the past Fall 2014 semester: the pre-assessment and the post-assessment using Educational Testing Service's (ETS) standardized Elementary Algebra Skills Assessments (EAS).

A summary of assessment data based on student learned outcomes from these multi-sections of College Algebra classrooms is presented. (Received September 16, 2014)

1106-R1-2430 **Cathryn G Menarchem*** (cgm6@geneseo.edu), 6 Heather Lane, Shoreham, NY 11786, and **John M Hines** and **Aaron Heap**. *ProofSpace: A Flipped Classroom Experience.*

At SUNY Geneseo, we have an online system called ProofSpace to facilitate a flipped classroom for a mathematical bridge course, Introduction to Mathematical Proofs. ProofSpace is a single digital location for housing video lectures and screencasts, associated quizzes and problem sets, and other related material. Its content is primarily focused on topics to help bridge the theoretical gap between lower-level, computation-based math classes and upper-level, proof-based math classes. The topics and tools learned here will help students as they venture further along their mathematical education path and should provide them with the necessary skills to become successful mathematicians. ProofSpace can also be a useful tool for students who want to review material they have already learned. Instructors can encourage students to use these resources within other courses as a means of reviewing prerequisite material. (Received September 16, 2014)

1106-R1-2433 **Wes Maciejewski*** (wes@math.ubc.ca), 1984 Mathematics Road, Vancouver, BC V6T1Z2, Canada. *An Evaluation of a Flipped Calculus Class.*

This is a preliminary report of a flipped calculus class evaluation currently underway in a multi-section course at the University of British Columbia. Six of the seven sections are using aspects of the flipped classroom to some degree. In the entirely flipped sections (four), students are required to watch a short video before class and respond to a pre-lecture questionnaire on the video. Class time is devoted to various interactive-engagement activities. Two of the sections require students to complete the pre-lecture quizzes, but the class time is largely lecture-based. The remaining section is a traditional lecture with weekly assignments. Background knowledge, measured with a test of basic skills, constructed in-house, and the Calculus Concept Inventory (CCI), and attitudes and perceptions of mathematics, measured using the Mathematics Attitudes and Perceptions Survey (MAPS), were evaluated at the start of the term. These will be matched with end-of-term CCI, MAPS, and course grade data. I expect to find gain scores on the CCI and improvements in attitudes and perceptions that correlate with the degree to which the section is flipped. (Received September 16, 2014)

1106-R1-2658 **Carrie Muir*** (carrie.muir@colorado.edu). *Using rotating student groups to increase participation and decrease anxiety.*

In this talk, I will describe a system of rotating student groups I use in an inverted course designed for elementary education students. I will discuss how mixing up student groups during a class activity increases student participation, and also builds a safe environment for students to ask questions and express uncertainty. The presentation will also include "nuts and bolts" ideas on how to set up the rotating group system for different class sizes, how to introduce the system to students, how often to use the system in a course, and structuring activities that can be used effectively with the system. (Received September 16, 2014)

1106-R1-2688 **Debbie Gochenaur*** (dlgochenaur@ship.edu), Department of Mathematics, MCT 250, Shippensburg University, Shippensburg, PA 17257. *Using a Hybrid Model to Build Math Skills in a Prerequisite College Algebra Course.*

Looking for strategies to address the high DFW rate in College Algebra, a roadblock course for many students, an inverted curriculum was developed for some sections of the course. After three semesters, with class sizes of about 40, multiple strategies for gaining student buy-in and overall engagement have been incorporated. The semester starts off with community building and working to help students develop a growth mindset utilizing some of Carol Dweck's strategies; helping students cultivate an open mind so that they can work towards developing new habits of mind with respect to algebra is crucial. This process occurs while students learn how to take effective math notes, essential for their next math course which is not inverted. Within the college algebra modified hybrid model, students watch videos outside of class and work on problems with classmates in class while micro lecture modules are incorporated for challenging topics that need reinforcement face-to-face. A gateway exam system, with proctored retakes, was developed for all sections of the course and covers foundational knowledge requiring a 70% average to pass into the next math course. Surveys show an increase in several positive indicators for the course. (Received September 16, 2014)

1106-R1-2737 **Terry L Barron*** (tbarron@ggc.edu). *Engaging the Introverted Learner using the Flipped Classroom in a Hybrid Calculus Class.*

The Flipped Classroom is a proven method of engaging students that results in deeper learning and higher achievement. A Hybrid format is a perfect environment for flipping the classroom if the pedagogical focus is "on-line with benefits." The benefit of the is that students are able to meet with the professor weekly to discuss problems and develop a deeper understanding of the material. Hybrid format classes that use the flipped classroom pedagogy are also an excellent means to engage introverted learners. Introverted learners often fall through the cracks in traditional lectures. Extroverted, gregarious students typically answer most questions in class even when we, as engaged teachers, try everything we can to make introverted learners participate. In this mixed methods design, results indicate that introverted learners feel more comfortable when instructors flip the classroom, which directly contributes to higher achievement. Increases in grades are attributed to both the Flipped Classroom method of teaching as well as innovative communication initiatives with students. Session participants will receive downloadable files for all resources presented, including surveys used, class preparatory quizzes and activities that promote student engagement. (Received September 16, 2014)

1106-R1-2814 **Jason A Miller*** (millerj@math.osu.edu), **Gary Kennedy** (kennedy@math.osu.edu) and **Elizabeth A Miller** (elizmiller@math.osu.edu). *Using Flipping Pedagogy in an Online Course.*

Excursions in Mathematics is a liberal arts math course which has traditionally been taught using large lectures and group-work based recitations. One major clientele for this course is nursing majors. With the advent of an online nursing program at Ohio State, it became necessary to put this course online (and quickly!). We wished to design an online course which still used group work as a central teaching method. This course has been taught online since Autumn 2013, and we have gradually developed a structure that bears a striking resemblance to a flipped classroom, only online! Students work through interactive online lessons asynchronously before class meetings. Then, the students attend synchronous online class sessions using Adobe Connect. In these class sessions, students are broken into groups using breakout rooms. Students work on problems collaboratively in their groups. They talk to each other using both microphones and a chat box and write on a common handout on the screen. The instructor jumps from group to group, asking leading questions and guiding the students. Despite some technical difficulties, we have found that this format really does engage students in learning the mathematics. (Received September 16, 2014)

Wavelets in Undergraduate Education

1106-R5-514 **Edward F Aboufadel*** (aboufade@gvsu.edu). *3D Printing and Wavelets, Continued.* Preliminary report.

3D printing is sometimes called "additive manufacturing technology", and these printers can be used to create solid, three-dimensional objects. Recently, desktop 3D printers have become more accessible to faculty and students, and in this talk, we will follow up on our talk from 2014, providing an update on how wavelets and other mathematical tools can be applied to create and print interesting objects. (Received September 01, 2014)

1106-R5-1592 **Helmut Knaust*** (hknaust@utep.edu), Department of Mathematical Sciences, The University of Texas at El Paso, El Paso, TX 79968. *Multi-Resolution Analysis for the Haar Wavelet: A Minimalist Approach.*

Multi-Resolution Analysis was developed in the 1980s by Mallat and Meyer as a tool to design wavelets. Even though the wavelets course I teach has a very applied flavor and is aimed at introducing my students to image processing applications, I include an introduction to multi-resolution analysis, albeit for the Haar wavelet only. This approach is expeditious, but nevertheless uncovers the connections between the continuous and discrete case, and reinforces the fundamental notion of orthogonality. (Received September 14, 2014)

1106-R5-1614 **Caroline Haddad*** (haddad@geneseo.edu), SUNY Geneseo, 1 College Circle, Genseo, NY 14454. *Using Wavelets as a Tool for Statistical Analysis of Big Data.*

Big Data has become a Big Concern in the last decade. In this presentation, I will discuss problems involving large amounts of information, where wavelets can be used to help "tame" the data. Examples might include image denoising, statistical recognition of dialect, and analysis of stationary time series. (Received September 14, 2014)

1106-R5-1914 **Ghanshyam Bhatt*** (gbhatt@tnstate.edu), Nashville, TN 37221. *Bases, Frames and associated operators in a Hilbert Space.*

The expansion formula for a signal in a Hilbert space requires a set of redundant or non-redundant vectors. Bases (non-redundant set) have been used for a long time. Over the past few years, frames (redundant or an over-complete spanning set) have been studied because of their applications. Bases, frames and other sequences in a Hilbert space can be associated with operators. The desired frames can be constructed by using the properties of the associated linear operators. In this talk, we provide frames as a sum of two frames for a given Hilbert space by using the operators associated with them. (Received September 15, 2014)

1106-R5-2292 **John C. Merkel*** (jmerkel@oglethorpe.edu). *Discrete Wavelets in a Liberal Arts Mathematics Course.*

In this talk I discuss the use of discrete wavelets in a liberal arts mathematics course. All students are required to take the course, which has no prerequisite. The course covers three topics and I taught discrete wavelets, focusing on applications, as one of the topics. (Received September 16, 2014)

1106-R5-2624 **David W Roach*** (droach@murraystate.edu), Faculty Hall 6C1-9, Murray State University, Murray, KY 42071. *Teaching wavelets to a freshman.*

In this talk, I will share a summary of the content that I used to teach wavelets to a freshman who was wanting to do an undergraduate research project. In this effort, I wanted to avoid making wavelets a mysterious black box, but instead provided illustrations of refinability, the cascade algorithm, orthogonal functions, and periodic extensions to give wavelets a concrete framework. This more heuristic development can be achieved without Fourier Transforms, Multiresolution Analysis, Spectral Factorization, and Trigonometric Polynomials. I will conclude with some topics that the student is exploring. (Received September 16, 2014)

1106-R5-2717 **Susannah Shoemaker*** (susannahcshoemaker@gmail.com), 1301 Ben Hur Drive, Houston, TX 77055, and **Deanna Needell**, **Wesley Kerr**, **Arpineh Asadoorian**, **Jessica Nadalin**, **Christian Ayala** and **Ryan McCarthy**. *Compressed Sensing Impacts the Statistical Inferences Made from fMRI.*

Compressed sensing is a new technology which demonstrates that high dimensional signals may be robustly recovered from few linear measurements. To make such a significantly underdetermined problem feasible, one assumes that the signal of interest is sparse. The key to its use in an imaging setting like MRI is that wavelet bases provide such a sparsifying transformation. The ability of CS to preserve the statistical properties of reconstructed signals is not yet well-understood. We provide evidence for the feasibility of statistical analysis on reconstructed signals through a case study of fMRI signals. A GLM was applied to each voxel time series of an original fMRI and a subsampled fMRI reconstructed via TV and wavelet minimization. We found evidence of non-normality in the residuals and some bias in the estimated regression coefficients. However, through comparison of the regions of activation for each task yielded from the original and the reconstruction from 50% of the data, we show that these biases do not preclude the use of CS for statistical analysis of different signals. This study provides some preliminary understanding of the problem of statistical analysis and parameter estimation in data compression, as well as advances our knowledge of the use of CS for fMRI. (Received September 16, 2014)

Well-designed Online Assessment: Well-Formed Questions, Discovery-Based Explorations, and Their Success in Improving Student Learning

1106-S1-991 **James H. Fife*** (jfife@ets.org), Educational Testing Service, Princeton, NJ 08541.
Don't Show Your Work! Online Assessment in CBAL Mathematics.

The goal of the Cognitively-Based Assessment of, for, and as Learning *(CBAL*$^{\text{TM}}$) research initiative at ETS is to develop research-based systems of summative and formative assessments in mathematics and English language arts that are meaningful learning experiences in and of themselves. In mathematics, extended computer-delivered tasks have been written, each built around a single theme. Each task consists of about 10 to 15 individual questions involving a variety of response types, including numeric responses, equations, graphs, short text responses, and extended explanations. Many of these responses are automatically scored. In this talk, I will share some of the *Do*'s and *Don't*'s that we have learned while working on this project. These lessons we have learned involve both how to present mathematics test items on the computer and how to write them so that they can be reliably scored automatically. This information will be useful to anyone writing mathematics test questions for presentation online, especially if they are to be automatically scored. (Received September 09, 2014)

1106-S1-1085 **Samuel Luke Tunstall*** (tunstallsl@appstate.edu). *Putting College Algebra Online: Breaking Away from Traditional Assessment* Preliminary report.

College algebra is one of many courses that fulfill Appalachian State.s quantitative literacy (QL) requirement. Traditional methods of assessment in the course include book problems and exams. When the course is placed online, however, there is significant potential to depart from this norm. An online platform provides a unique means of engaging students in quantitative discussions and research . to draw students. attention through contextualized projects and discussions. Appalachian.s online version of college algebra includes weekly forums related to news topics as well as a few data-driven projects that require students to find and/or analyze data. A key in making such assessment successful is to ensure that the assignments remain true to the material and course QL goals while also being meaningful to students. In this talk I will discuss my experience in transforming college algebra assessment for the online environment, as well as give tips for those interested in putting other math courses online. (Received September 10, 2014)

1106-S1-2032 **Nathaniel Rounds*** (nathaniel.rounds@reasoningmind.org) and **Michael Von Korff**.
Test Well and Test Often: Differentiating Instruction Using Micro-Assessment.

Good instruction uses assessments to guide teaching decisions. Unfortunately, periodic tests offer only an incomplete snapshot of student learning. In an online, blended-learning environment, continuous micro-assessments can form the basis for real-time instructional decisions. We discuss how Reasoning Mind implements micro-assessments and our plans for the future. (Received September 15, 2014)

1106-S1-2809 **Paul E Seeburger*** (pseeburger@monroecc.edu), 1000 E. Henrietta Rd., Rochester, NY 14623. *Creating Effective Online Homework Problems in Intermediate Algebra (Using WeBWorK).* Preliminary report.

Many of us assign our students online homework problems in our courses. These online problems can be valuable learning tools, helping our students spend more time practicing the skills and concepts we teach them. But are we assigning pedagogically well-designed problems or just problems that ask for a single answer (even word problems) and follow a clear pattern? Even the best students sometimes just look for patterns to get the right answer (or look up the answer on Wolfram Alpha or another online math engine), worrying about how to work out the problem later (if they find time). I believe we train students to do math problems by the way that we assess them. Problems that only require a numerical (or even symbolic) answer that can be found easily using a calculator or a website train students to use these tools, and may fail to train them to work out the problems in the way that we show them in class and require on exams (showing clear work). Without help, students can also become frustrated in these one-answer problems when their answer is not accepted. I will present some of my attempts to address these issues in problems I have created or adapted using WeBWorK and propose some best practices for creating online homework problems for algebra (and other math) classes. (Received September 16, 2014)

1106-S1-2839 **Elizabeth A Miller*** (elizmiller@math.osu.edu), **Carolyn Johns** (johns.125@math.osu.edu) and **Jason A Miller** (millerj@math.osu.edu). *Interactive Online Lessons using Articulate Storyline.*

In some sections, we have replaced large lectures with interactive online lessons created with Articulate Storyline. These lessons combine content delivery and assessment to provide feedback to students as they are learning. This allows students to make sound judgements about questions like, "Did you really understand this point?", "Are you ready to learn the next idea?", and "Do you need to see more examples?". Online lessons begin with computational and conceptual goals for the lesson. Within the lesson, students watch short videos, interact with slides, answer quiz questions, and make decisions about which examples and how many examples they try. When students answer quiz questions incorrectly, they are given instantaneous feedback and are often sent back to a previous slide to review before trying again. At the end of the lesson, students answer essay questions about what they have learned and what they are still having trouble with. These answers go to their recitation instructors to help them prepare for class. Although these lessons are a graded component in the hybrid and online courses, thousands of students in the traditional sections work through these lessons as well. Come see how you can use these calculus and liberal arts math lessons for your course. (Received September 16, 2014)

1106-S1-2882 **Maria Mendiburo*** (mendiburo@carnegiefoundation.org), 51 Vista Lane, Stanford, CA 94305, and **Scott Strother**. *Implementing Multiple Forms of Assessment in Carnegie's Community College Pathways' Online Platform to Support Student Learning and Achievement in Community College Developmental Mathematics.*

Carnegie's Community College Pathways aim to improve student success in developmental and college level mathematics while maintaining rigorous learning outcomes. The Pathways utilize an online platform that allows students to assess their knowledge during and after lessons and at the end of modules. The Pathways also include a common summative assessment, which is currently transitioning to an online system. This session will unpack the challenges faced with each form of assessment and our strategies for addressing them. The greatest challenge with the formative assessments is engaging teachers with the results and building their understanding of the implications each assessment can have. For example, we have learned that simply completing the assessments predicts higher success. To address this challenge, we have created a live dashboard that describes students' progress and results on the online assessments. This helps students engage with the platform and track their conceptual understanding while allowing teachers to monitor online engagement and learning progress. The online summative assessment presents challenges for proctored internet access but will allow a richer diversity of item formats, such as those developed for the CCSSO, to be accessed through multiple media. (Received September 17, 2014)

1106-S1-2923 **Monica M VanDieren*** (vandieren@rmu.edu), Department of Mathematics, Robert Morris University, 6001 University Bvld, Moon Township, PA 15108. *Transitioning from discovery-based worksheets to online explorations in a multi-variable calculus class.*

In this presentation we will discuss our experience in modifying discovery-based in-class worksheets to online exploration activities using WebWork and CalcPlot3D. We will discuss in detail our experiences with an exploration geared to finding a tangent plane to a surface at a point. (Received September 17, 2014)

What Makes a Successful Math Circle: Organization and Problems

1106-S5-60 **Bogdan D. Suceava*** (bsuceava@fullerton.edu), 800 N State College Blvd, 154 McCarthy Hall, Department of Mathematics CSUF, Fullerton, CA 92834-6850. *Fullerton Mathematical Circle: The First Three Years.*

The very idea of a mathematical circle is rather new to the U.S. and even less known in Orange County than in other parts of the country. The concept of the Fullerton Mathematical Circle is inspired from similar activities done in Central Europe over the last century with Universities offering enrichment programs to interested young gifted mathematicians. Our initiative is the only Mathematical Circle in the USA that draws its inspiration from the activities of Gazeta matematica, a monthly journal with continuous publication since 1895 by the Romanian Society of Mathematical Sciences. The project consists of offering mathematical sessions for gifted middle school and high school students. We will show how several research projects have been developed by our students starting from Gazeta matematica's problems. (Received June 06, 2014)

1106-S5-540 **Victoria Kofman*** (drkofman@comcast.net), Vika School, 1067 Lake Cook Rd., Wheeling, IL 60090. *Chunking, Auxiliary Elements, and Commutation as a Topic for Math Circle.*

In the problems we design, students must apply several problem-solving techniques to find perimeter or area. They divide figures into several parts (chunking), move these parts around without changing the total area/ perimeter (commutation), and/or draw additional lines and figures (auxiliary elements) onto the figure to reveal a path to the solution.

The students start with perimeter problems, and their solutions are discussed in terms of problem solving techniques applied. Then, students work with area problems that can only be solved by applying the same techniques.

Our unit provides two different types of geometry problems that teach problem solving terminology and techniques, while helping students to recognize similarities between different types of problems. (Received September 02, 2014)

1106-S5-633 **Dave Auckly*** (dav@math.ksu.edu), Mathematics Department, Kansas State University, Manhattan, KS 66502. *Problems from the Navajo Nation Math Circle.*

We will describe the Navajo Nation Math Circle project, and present several activities that were used in the project over the past year. (Received September 03, 2014)

1106-S5-728 **Maria Droujkova*** (droujkova@gmail.com), 309 Silvercliff Trl, Cary, NC 27513. *1001 Circles: The Surprising Diversity.*

What is a mathematical circle from the point of view of its leader and participants? What types of groups call themselves "mathematical circles"? What other entities, such as summer camps, learning coops, or maker spaces, form the larger social ecosystem where math circles are situated? Who are leaders of math circles, how do they grow, and what support do they need?

The "1001 Circles" paper will answer these and other overarching questions. It summarizes findings from a series of interviews with math circle leaders and mathematics education project leaders, as well as observations from open online courses for parents and math circle leaders at Natural Math. It will use particular examples from mathematical circles to illustrate general points. (Received September 05, 2014)

1106-S5-792 **Tzvetalin S. Vassilev*** (tzvetalv@nipissingu.ca), Dept. of Computer Science and Mathematics, 100 College Drive, Box 5002, North Bay, Ontario P1B 8L7, Canada. *Math Circles in North Bay – the Northern Experience.*

Identifying mathematically talented children and working with them in various forms to help them achieve their full potential has been a priority in many countries around the world in the last 50 years. In the last 20 years, special attention has been paid to this in North America as well. One of the most common forms is the so-called Mathematical Circles. In this paper, we describe the experience of a group of faculty and students at Nipissing University in running the Math Circles in North Bay, Ontario. North Bay, Ontario is a small town with the population of about 54,000 people, located 350km north of Toronto on the intersection of two major routes, Highway 11 and Highway 17 (Trans-Canada Highway). North Bay is an important economic centre for the region; however, due to its small population and remote location, it is quite different from the large urban areas in North America in many aspects. These differences have significant impact on the scale and the way mathematical education is delivered, especially when it comes to working with mathematically talented children. (Received September 06, 2014)

1106-S5-1290 **Diana White*** (diana.white@ucdenver.edu). *One Leader's Perspective on How to Run a Successful Math Teachers' Circle Program.*

Now entering its fifth year, the Rocky Mountain Math Teachers' Circle is one of the oldest continuously running Math Teachers' Circles in the country. In this talk, we reflect on both successes and lessons learned from the program. We address logistics, treatment of teachers, establishing a problem solving culture, and how we choose both problems and facilitators. We connect portions of this talk to lessons learned by the author as part of a team researching multiple Math Teachers' Circles across the country. (Received September 11, 2014)

1106-S5-1626 **David Scott*** (scott@pugetsound.edu), Math/CS #1043, University of Puget Sound, 1500 N. Warner St., Tacoma, WA 98416. *Good Problems: Planning in Context.* Preliminary report.

The talk will discuss issues in choosing/crafting good problems for a Math Circle or Math Teachers' Circle. What are the important factors to consider, what are sources of good problems, and how can you adjust problems to the participants you have. (Received September 14, 2014)

1106-S5-1897 **Mary L Garner***, 4621 Ivygate Circle, Atlanta, GA 30339, and **Virginia Watson** (vwatson@kennesaw.edu), Kennesaw State University, Department of Mathematics, Kennesaw, GA 30144. *Assessing the Influence of a Mathematics Elementary Teachers' Circle.* Preliminary report.

In 2011, we formed a mathematics teachers' circle for elementary teachers from five urban schools. The 31 teachers participated in a three day immersion workshop in February and then three two-hour math circle meetings during the remainder of the year. Teachers received a stipend for their participation under a larger Teacher Quality Grant. To evaluate the impact of the circle, participants did a pre- and post-problem solving activity, responded to a pre- and post-attitude survey, and were asked to respond to journal prompts at the end of math circle meetings and during each week of their teaching. We sought to answer three research questions:

1. Does participation in Math Teachers' Circles increase participants' use of problem solving as a teaching process, including their ability to evaluate (recognize, promote, initiate, engage) their students' problem solving?, 2. Does participation in Math Teachers' Circles improve participants' ability to engage in problem solving? 3. Does participation in Math Teachers' Circles change teachers' attitudes towards mathematics and their identification of themselves as mathematicians?

Our presentation will focus on exactly how we conducted the study, the pitfalls we encountered, and brief overview of our initial findings. (Received September 15, 2014)

1106-S5-2056 **Darren M Garbuz*** (dgarbuz@slu.edu). *Middle School Students and Yarn: Picture-Hanging Puzzles.*

Picture-hanging puzzles involve wrapping string around nails in a wall and observing if the picture attached to the string hangs or falls. This talk discusses the successful implementation of some picture-hanging themed math circles that were given to groups of middle school students. (Received September 15, 2014)

1106-S5-2107 **Martha H Byrne*** (byrnema@earlham.edu), Earlham College, Drawer 138, 801 National Rd W, Richmond, IN 47374. *Divisibility and Logic - A Problem for Math Circles.*

This talk will present a problem accessible to either students or teachers. The solution uses only common divisibility rules and logic to construct a 10-digit number. This problem successfully engaged small groups at an established math teachers' circle in the southwest. (Received September 15, 2014)

1106-S5-2250 **Japheth Wood*** (jwood@bard.edu), PO Box 5000, Annandale-on-Hudson, NY 12504-5000, and **Lauren Rose**, **Eliana Miller** and **Jake Weissman**. *Mathematics and Logistics of the Bard Math Circle.*

The Bard Math Circle provides math enrichment for middle school students in the Mid-Hudson Valley, including library math circles, math contests and a summer math C.A.M.P. We will share our favorite math problems and our least favorite organizational problems. (Received September 16, 2014)

1106-S5-2336 **Jane H Long*** (longjh@sfasu.edu), Department of Mathematics & Statistics, P.O. Box 13040, SFA Station, Nacogdoches, TX 75962-3040. *Circle of Friends.*

Stephen F. Austin State University's East Texas Math Teachers' Circle is now in its second year and has had a very successful start thanks to mutually beneficial arrangements with some unexpected partners. Generous support from a federally funded program (GEAR UP) has both encouraged us to allot some time to classroom connections and provided us with a core group of teachers. Seed grants and a relationship with our regional education service center have also been helpful. In addition to highlighting our most successful problems and the diversity of our session topics, we will discuss the roles of our partners and the structure of the circle activities inside and outside of scheduled meetings. (Received September 16, 2014)

1106-S5-2623 **Alex Sprintson*** (spalex@tamu.edu), College Station, TX 77843, and **Phil Yasskin**, **Frank Sottile**, **Kaitlyn Phillipson** and **Trevor Olsen**. *Integrating Engineering Concepts in Math Circle Activities.*

In this talk, we will share our experience in integrating concepts from the broad areas of engineering into the activities of Texas A&M Math Circle. Texas A&M Math Circle is a joint project between the Departments of Mathematics and Electrical and Computer Engineering at Texas A&M University. Over the last few years we have developed several activity modules covering the areas of boolean algebra and circuit design, probability theory, coding theory, cryptography, and information theory. The key to the success of these activities was to adapt them to students' level of mathematical maturity and present them in a way that would be accessible to the students. (Received September 16, 2014)

1106-S5-2771 **Gabriella Pinter*** (gapinter@uwm.edu), P.O. Box 413, Milwaukee, WI 53201-0413.
Favorite Problems from the UWM Math Circle.

The University of Wisconsin Milwaukee Math Circle is a weekly enrichment program for students in grades 7-12. We focus on collaborative problem-solving, open ended explorations, generalizations and posing new problems. A few of our most memorable problems and discussions will be presented. (Received September 16, 2014)

1106-S5-2797 **Mark A. Brown*** (mabrown@mnu.edu). *Math Teachers' Circles: A Time of FUNstration.*

Each of the last two summers the Heartland Math Teachers' Circle met at MidAmerica Nazarene University to have a weeklong intensive time of fun and frustration (a.k.a. FUNstration). The group of middle school teachers also meets 2 or 3 times each semester during the school year. In this session I will talk about the organization of the weeklong workshop and the organization of the individual sessions including a brief description of the types of problems used. Furthermore, I will share teacher comments regarding their experience, and I will share lessons I've learned throughout the process. (Received September 16, 2014)

1106-S5-2847 **George F McNulty*** (mcnulty@math.sc.edu), Department of Mathematics, University of South Carolina, Columbia, SC 29208, and **NIeves A McNulty** and **Douglas B Meade**.
Know a good problem?

"A middle school math teacher and a math graduate student looking for a dissertation topic walked into a bar. Know a good problem?"

We launched the South Carolina High Energy Mathematics Teachers' Circle, with 15 middle school teachers and a leadership team of 9, in 2012 with a summer immersion workshop. During the second year our circle expanded to 30 middle school and secondary teachers, and we continued our pattern of immersion workshop, monthly four hour Saturday meetings during the academic year, and an emergence workshop in June. We used some time to discuss classroom issues, but the heart of each of our meetings was to tackle mathematical problems in small groups. So while the teachers were intent on developing their abilities to solve mathematical problems, the leadership team was developing their abilities to invent and frame mathematical problems. This presentation will provide some lessons we have learned about devising good mathematical problems, with examples and counterexamples. (Received September 16, 2014)

1106-S5-2855 **Lori Beth Ziegelmeier*** (lziegel1@macalester.edu). *A Math Circles Camp at Colorado State University.*

There are many opportunities for mathematicians to work within their community to engage young students in mathematics. One such opportunity comes in the form of Math Students' Circles, sometimes referred to as simply Math Circles – venues that give mathematicians experience in introducing children to topics not typically seen in school curricula in an exciting, hands-on format.

The Colorado State University Math Circles program has been running for 6 consecutive years as a week-long summer camp designed for students entering 8th and 9th grades. To date, over 230 students have participated in the program, with the combined efforts of over 15 faculty and 25 graduate students running the program. Our program consists of interactive activities, a treasure hunt, and a unique split of students by gender for most activities. In this talk, we will discuss the structure of our program, some of the most successful activities, and observations of group dynamics. (Received September 16, 2014)

1106-S5-2903 **Alessandra Pantano*** (apantano@uci.edu) and **Casey Kelleher** (clkelleh@uci.edu).
Conveying group theoretic concepts to middle schoolers at the UCI Math Circle.
Preliminary report.

One of the most rewarding aspects of designing the Math Circle curriculum is the ability to transform some of the most sophisticated mathematical concepts into something both engaging and comprehensible to middle school students. This is not an easy task. Can a student with no geometry or algebra 2 background develop an intuition for the classification of the 7 Frieze groups and understand the differences among the 17 wallpaper groups?

In this talk, we describe some of the efforts undertaken by the UCI Math Circle Team to convey an appreciation for abstract Group Theory concepts to middle school students, through clever explorations, well-crafted visuals, engaging worksheets and fun manipulatives. (Received September 17, 2014)

1106-S5-2904 **Zvezdelina E Stankova*** (stankova@mills.edu), 5000 MacArthur Blvd, Department of Mathematics & Computer Science, Mills College, Oakland, CA 94613. *The Future of a Successful Math Circle.*

The Berkeley Math Circle (BMC), one of the oldest math circles in the US and currently under the financial umbrella of the brand new United Math Circles Foundation, has grown to 400 students in 12 sessions every week on UCB campus, splitting over two buildings and hosted by three departments of the university. What makes the circle so successful also makes it hard to sustain. What makes parents and students drive for hours in heavy traffic to the 6pm sessions and constantly raises the demand for more space in the circle? Can the circle continue in its present form, or should it change? What advantages and possibilities does the new Foundation give and could other circles follow?

We shall examine these questions in the context of the ever evolving, sometimes aspiring, and often contradicting movements in the math curriculum in the K-12 public and private schools throughout the Bay Area. (Received September 17, 2014)

General Session on Assessment

1106-VA-551 **Kyle Riley*** (kyle.riley@sdsmt.edu), Dept. Math & CS / SDSM&T, 501 East Saint Joseph Street, Rapid City, SD 57701. *Use of Course Embedded Assessments to Evaluate Teaching and Student Learning.* Preliminary report.

South Dakota School of Mines & Technology policy requires that student opinion surveys from classes must be a measure, but not the only measure for evaluating teaching. In recent years, we have developed the Course Embedded Assessment tool to gather student learning in relation to learning outcomes for each course. This tool has been refined from a rather limited formal assessment to a broader evaluation that has engendered an electronic archive as a resource for department faculty. This preliminary report will discuss lessons learned along with future goals with this assessment tool. (Received September 02, 2014)

1106-VA-701 **Georgianna L Martin*** (gmartin@hpu.edu), 45-045 Kamehameha Highway, HLC 311C, Honolulu, HI 96744, and **Tara C Davis** (tdavis@hpu.edu), 1164 Bishop St, UB210A, Honolulu, HI 96813. *Quantitative Reasoning: Developing an Assessment Strategy From a Non-Existent State.* Preliminary report.

In 2013-14, Hawaii Pacific University piloted four Institutional Learning Outcomes. One of these outcomes was Quantitative Reasoning-Students will interpret, calculate, analyze, represent, and clearly communicate quantitative information through Mathematical tools (e.g. equations, graphs, or diagrams).

The authors were tasked with this pilot. 279 signature assignments in five different math courses were collected and assessed. We will discuss the details of the pilot from inception to completion, including the choice of courses, development of a RUBRIC and signature assignments, the strategy for gaining faculty buy-in, and the evaluation of the artifacts through norming sessions and faculty grading sessions. Both the signature assignments and the assessment plan were analyzed for effectiveness and efficiency.

We concluded that our teaching of interpretation, calculation and analysis, particularly in Pre-Calculus and Calculus needs improvement. The department decided to conduct the assessment annually, planning to implement improvements on an iterative basis. The true value of this pilot came from the realization of an assessment strategy from a non-existent state. This presentation will also address specific obstacles we encountered as a result of our assessment ignorance. (Received September 04, 2014)

1106-VA-820 **Josip Derado*** (jderado@kennesaw.edu), 1000 Chastain Rd, Kennesaw, GA 30144, and **Mary L Garner** (mgarner@kennesaw.edu), 1000 Chastain Rd, Kennesaw, GA 30062. *Point Reward System: A Method of Assessment that Accommodates a Diversity of Student Abilities and Interests and Enhances Learning.*

A prevalent problem that we are presently facing in teaching college mathematics is a large diversity in students' abilities and their interest in mathematics. In this paper we present the Point Reward System (PRS), a new method of assessment which resolves this problem and enhances learning. The PRS is easy to implement and it does not require additional resources. We compare PRS to the traditional teaching method which prevails at the universities and colleges today. The data show that PRS has significantly lower WFD rates than the traditional teaching method. PRS is also more successful in keeping students engaged in course throughout the semester and it has more impact on students' learning. (Received September 07, 2014)

1106-VA-992 **Alison Ahlgren Reddy** (ared@illinois.edu), 1409 W. Green Street, Urbana, IL 61801, **Michael Grant*** (michael.grant@colorado.edu), University of Colorado at Boulder, 40 UCB, Boulder, CO 80309-0040, and **Marc Harper** (marc.harper@gmail.com), 8063 Redlands St #305, Playa del Rey, CA 90293. *Placement Program Best Practices: Research from University of Colorado Boulder and University of Illinois.* Preliminary report.

Students enter higher education with a wide variety of mathematical backgrounds. Many are often improperly placed together in very large first year mathematics courses that have very low success rates. Students that fail their first courses may face multiple devastating consequences and, consequently, are substantially less likely to ever complete a degree.

Properly placing students into an appropriate first math or math-dependent course is paramount to their success, especially in the first two years of college. Accurate placement requires an accurate, recent assessment. Standard test scores are often out of date and not particularly predictive of student success.

We will discuss our respective placement programs, share data, and discuss student and program commonalities from the CU Boulder and University of Illinois Placement Programs which have assessed over 70,000 students. (Received September 09, 2014)

1106-VA-1583 **Amanda M. Harsy*** (harsyram@lewisu.edu), Lewis University, Romeoville, IL 60446. *Oral and Mastery Based Testing in a Real Analysis Course.* Preliminary report.

In this talk we will discuss oral and mastery-based testing in an undergraduate Real Analysis course. The main goals of these alternate assessment methods are to decrease test anxiety and increase full understanding of the concepts of Analysis. In mastery-based testing, students are given problems in which they can only receive full credit on the problem after they demonstrate mastery of the concept being tested. Each test includes similar questions over the same concepts from previous tests which allows students who have not mastered an idea to retest and fully comprehend old concepts. Once a student receives full credit for a question, they need never attempt the question again. Students also met with the instructor to present proofs as an oral exam. This allowed the instructor to ask questions to determine whether a student fully understood the step by step process of the proof. It also provided students who were stuck a chance to be given a hint from the instructor and continue from that point. Both testing methods are designed so that test anxiety decreases since one bad exam grade or getting stuck on a proof will not necessarily tank their overall grade. This talk will discuss the benefits, shortcomings, and challenges of implementing these alternate assessment techniques. (Received September 14, 2014)

1106-VA-1862 **Ashley S Johnson*** (ajohnson18@una.edu). *The 'Choose Your Own Adventure' Grading Scheme.*

Since no two students are the same, it seems unlikely that having an identical division of the weights of the various components of the final grade (exams, homework, etc.) for all students in a class is the best option. For the past two semesters, I have implemented a grading scheme customized to each student; each student fills out a grade sheet choosing their weights for each component of the course within given ranges. In this talk, I will discuss the nuts and bolts of this method as well as its advantages and student response. (Received September 15, 2014)

1106-VA-2226 **Sijie Liu*** (sliu28@crimson.ua.edu), University of Alabama, Mathematics Department, Gordon Palmer Hall, Box 870350, Tuscaloosa, AL 35487. *A Clustering Method Based on Adaptive Metaheuristic Algorithm for Teaching Assessment.*

A correct and comprehensive class evaluation result will stimulate the Instructors' enthusiasm for teaching. The study aims to develop an efficient approach for improving the accuracy of teaching quality assessment by using an adaptive Clustering approach. The introduced clustering technique is based on k-means such that the data is partitioned into K similarity groups (clusters). However, traditional k-means is not perfect because of highly relying on the selection of initial conditions and can easily get involved in the premature convergence problem. We will present an adaptive Cat swarm optimization (CSO) algorithm, and the new CSO clustering approach was tested and results indicated the modification made on the CSO can obtain more accurate outcomes comparing to the traditional k-means method. We can consider it as a sufficiently accurate clustering method to attribute to our future teaching assessment. (Received September 16, 2014)

General Session on History and Philosophy of Mathematics

1106-VB-62 **Christina Tran*** (cnt_tran@csu.fullerton.edu), 800 N State College Blvd, 154 McCarthy Hall, Department of Mathematics CSUF, Fullerton, CA 92834-6850, and **Bogdan D. Suceavă** (bsuceava@fullerton.edu), 800 N. State College Road, 154 McCarthy Hall, Department of Mathematics CSUF, Fullerton, CA 92834-6850. *On Sophie Germain's Essays.*

Sophie Germain (1776-1831) is remembered today for introducing the mean curvature in differential geometry, and is better known for her work in number theory and elasticity. In our presentation we discuss how relevant and interesting are her essays. We also present new translations of several fragments of her texts. (Received June 07, 2014)

1106-VB-120 **Ronald L Merritt*** (ronald.merritt@athens.edu), 300 North Beaty Street, Athens, AL 35611. *An examination of the mathematics educations of select Presidents of the United States.*

Some Presidents of the United States, such as James A. Garfield or Thomas Jefferson, clearly advocated, applied or contemplated mathematics. However, more than these two Presidents studied mathematics at a range of complexity. What did the mathematics education of some of our United States Presidents include? What were the personal opinions of some of the United States Presidents regarding mathematics? To what extent might have their mathematics education informed them about the STEM-related policies of their day, if such policies existed? (Received July 21, 2014)

1106-VB-537 **Jacqueline S Ward*** (jward@lbcc.edu), Long Beach City College, Dept. of Math & Engineering, D-159, 4901 E. Carson St. (Mail Code B2), Long Beach, CA 90808. *Reaching for Cultural Roots of The Representamen: Developmental Math Students' Internal Signs.*

This study explores a cultural basis for beliefs held about mathematics. The investigation focuses on, (1) the cultural characteristics and practices that contribute to learners' beliefs on mathematics, and (2) how explicitly creating experiences for students to make connections between classroom mathematics and their individual cultures may affect these beliefs. Peirce's semiotic triad is employed to provide a framework for analysis. Whereas mathematics is rich in symbols, with a focus on the affective domain here, the "sign," or in Peircian language: the Representamen, is regarded as a malleable internal construct created and held by the learner. As individual learners make sense of mathematics bringing to bear their own cultural identities, these Representamen are thus posited to be inherently cultural in nature. Freehand drawings by learners and expository reflections are used to gain insight into the cultural roots of these internal signs. Moreover, students will be introduced to the field of ethnomathematics and asked to provide examples from their unique cultures to illustrate mathematical concepts taught in the course. Examples of student work and conclusions of the study will be presented. (Received September 01, 2014)

1106-VB-611 **Daniel J. Curtin*** (curtin@nku.edu), Department of Mathematics and Statistics, Northern Kentucky University, Highland Heights, KY 41099. *Jan De Witt: The Equations for Curves.*

Jan De Witt's two-volume *Elementa curvarum linearum (Elements of Curves)* appeared as part of Frans van Schooten's famous Latin edition of Descartes' *Géometrie*. The second volume was the first systematic treatment of lines and conic sections to start with equations and then identify the known curve represented by the equation. This was a major step in moving towards the modern approach of starting with equations. Previously the usual starting point had been a geometric or mechanical definition of the curve. De Witt's examples are accessible to students with a pre-calculus background, being similar to what they already know. However, students would be challenged to think a bit more deeply about their knowledge of these basic curves. (Received September 03, 2014)

1106-VB-656 **Salar Y. Alsardary*** (s.alsard@usciences.edu), 600 S. 43rd St., Philadelphia, PA 19104, **HweeJung Kim**, 600 S. 43rd St., Philadelphia, PA 19104, and **Julie George**, 600 S. 43rd St., philadelphia, PA 19104. *A New Technique to Solve the Instant Insanity Problem.*

Instant Insanity consists of four cubes, each of whose six faces are colored with one of the four colors: red, blue, white, and green. The object is to stack the cubes in such a way that each of the four colors appears on each side of the resulting column. Traditionally, this could be solved using graph theory. However, in this talk, we introduce a new technique to solve the problem without using graph theory. We also used a Perl programming language to implement the new approach for the Instant Insanity. (Received September 04, 2014)

1106-VB-707 **Shigeru Masuda*** (hj9s-msd@asahi-net.or.jp), Tama-cho, 2-18-5, Fuchu, Tokyo 183-0002, Japan. *Confusion and Unity in Handling of Heat Motion and Fluid Motion in the 19th Century.*

Fluid is freely movable continuum. Wave is the transmitting phenomena of variation occurred in a point of space with the finite velocity.

These handling owes to the arrival of idea of continuum, on which, above all, we summarize the topics of heat and fluid as the background from the viewpoint of mathematical history in 18-19th centuries as follows :

1) On the attraction and repulsion of molecule, Laplace starts with the analysis of capillarity and Navier with formulation of elastic solid and fluid 2) Navier depends on Fourier's principle of heat molecule. The then physico-mathematicians had little evaluated Navier until the top of 20th century. 3) Poisson points out strongly Navier's hypothesis on molecular structure in natural state and Fourier's invalid handling of De Gua's theory into the transcendental equations. 4) We introduce Prévost's preceding work to Fourier. Formulating of heat motion in the fluid, Fourier had submitted the paper, in which he seems to aim the unity of hydro- and thermodynamics 5) The trigonometric series is introduced in the process of expression of wave equations of sound by Lagrange in 18th century and completed by the follower in 19th century. (Received September 14, 2014)

1106-VB-1593 **Lawrence A. D'Antonio*** (ldant@ramapo.edu), Ramapo College, 505 Ramapo Valley Rd., Mahwah, NJ 07430. *The Mathematics of the Encyclopédie.* Preliminary report.

One of the greatest intellectual achievements of the 18th century was the *Encyclopédie* edited by Denis Diderot and Jean d'Alembert. The work, comprising 28 volumes with over 70,000 articles written by more than 130 contributors, attempted to give a systematic overview of human knowledge at that time. In this talk we will give an overview of the writing of the *Encyclopédie* and its place in the Enlightenment. We will focus on the mathematical articles in the *Encyclopédie*, many of which were written by d'Alembert, such as the well-known article on the concept of limit. We will consider the question of what is the role of mathematics in the structure and goals of the *Encyclopédie*? (Received September 14, 2014)

1106-VB-2495 **Treena Basu*** (basu@oxy.edu), 4911 Range View Avenue, Los Angeles, CA 90042, and **Lokenath Debnath**. *A Short History of Statistics and Its Application.* Preliminary report.

This paper deals with a short history of statistics and its applications. Included are mean, median, mode, midrange, errors of observations, Bernoulli's law of large numbers, principle of least squares, standard deviation and variance of data. Special attention is given to Gauss' derivation of the method of least squares with the formula for the variance of the continuous probability distribution. Fisher's celebrated maximum likelihood method for estimation of parameters is presented with examples of the unknown parameters in binomial, Poisson, and normal distributions. This is followed by a brief historical introduction to regression and correlation with regression curves, correlation coefficients and their properties. Some examples of applications are mentioned. Included is also some modern information that puts students, teachers, and statisticians at the forefront of current advanced study and research in analytical and computational aspects of statistics. (Received September 16, 2014)

1106-VB-2879 **John R. Botzum*** (botzum@kutztown.edu), 5528 Heather Lane, Orefield, PA 18069. *Should it be the Dirichlet Rearrangement Theorem?* Preliminary report.

The Riemann Rearrangement Theorem states: A conditionally convergent infinite series can be rearranged to converge to any real number , or to diverge to infinity , or to diverge to negative infinity, or to diverge by unbounded oscillations. However, in Riemann's own words(Habilitationsschrift,1859), he suggests that he was aware of,and acknowledged, Dirichlet's establishment of the result in Crelle's Journal,1829.The talk will discuss whether the theorem should more accurately be attributed to Dirichlet. (Received September 16, 2014)

General Session on Interdisciplinary Topics in Mathematics

1106-VC-253 **Jan Rychtar*** (rychtar@uncg.edu), Department of Mathematics and Statistics, UNCG, Greensboro, NC 27412. *Mentoring Interdisciplinary Research Projects.*

In 2006 faculty members within the Departments of Biology, Mathematics and Statistics and the Office of Undergraduate Research at the University of North Carolina at Greensboro came together to develop an undergraduate MathBio program supported by the National Science Foundation. Our objectives are to generate new knowledge at the interface of mathematics and biology, showcase the importance of mathematics outside the discipline, increase the use of mathematics and statistics in the field of biology, and guide students to an increased proficiency of research skills while preparing them for interdisciplinary graduate education. During this talk, we will address how we began and how we evolved the program over the years; talk about the successes and pitfalls of the program and discuss challenges we face as we move forward. (Received August 15, 2014)

1106-VC-285 **Pawel Dlotko*** (dlotko@sas.upenn.edu). *Topological sensor networks.*
Distributed sensing, information and computation based on sensor networks comprise a new frontier in engineering and science. Cheap, easily available sensors performing collectively complicated tasks are forthcoming, and in security and other applications involving sensor networks the coverage of a region of interest is of a high importance. In this talk we will quickly summarize progress made over the last eight years in topological sensing and detection, and propose a revised definition of topological coverage which makes all the topological criteria more intuitive. Then we will consider a problem of sensor repairs in working sensor network which used to cover the region of interest. (Received August 19, 2014)

1106-VC-367 **Michael Bauer**, **Xiaowen Chang** and **Michael Conway*** (mbconwa@emory.edu). *Quantifying Option Implications.* Preliminary report.
We introduce relevant financial concepts, and describe how mathematical tools can be used to extract information about the market's expectations and risk preferences from daily, observable options market prices on the S&P 500. This information takes the form of a probability density function, known as the Risk-Neutral Density (RND). This project investigated parametric and non-parametric methods for extracting these RNDs. While neither method proved to be superior, we found that the non-parametric method could be improved. Assuming no prior knowledge, we introduce our major tools, including splines and the Generalized Extreme Value (GEV) Distributions, and show how they can be used in a financial context. Our results are based on the daily implied risk neutral densities that we derived for 3800 days. We used the density curves to analyze various market crashes and events during the past two decades. Using regression, we tried to predict option prices for very short periods, which is new to the literature. We also tried to understand how expectation and risk preferences are incorporated into U.S. stock prices. (Received August 25, 2014)

1106-VC-1095 **G Peng***, gpeng@mdanderson.org. *Network flow as a systems biology approach to understand the DNA repair network in cancer.* Preliminary report.
The DNA repair process plays a fundamental role in maintaining genomic integrity and preventing the development of cancer. Hundreds molecules have been identified in the DNA repair pathways. However it remains to be a key question: how can we understand the DNA repair process as a functional network instead of studying each individual component? We present a model where the concept of flow network is modified and used to model the impact between genes involved in the DNA repair network. As a result, key target genes can be predicted that have significant influence on DNA repair capacity of cancer cell. This study provides proof-of-principal that advanced mathematical concepts and theories can be used to guide the target selection for understanding cancer etiology and designing therapeutic strategies. (Received September 10, 2014)

1106-VC-1201 **Adam Fuller** and **Jeremy Trageser*** (s-jtrages1@math.unl.edu). *Math in the City.*
Math in the City is an interdisciplinary course that takes a hands-on approach to learning and fosters real-world experience. Students are given data obtained from a local collaborator and tackle problems of national or local concern while learning about modeling.

This talk will deal with the presenter's experience with the course in the Fall of 2014. Students worked on problems involving snow removal and road repair in Lincoln. Statistical analysis as well as linear programming was utilized to solve a variety of problems related to the data. (Received September 11, 2014)

1106-VC-1343 **Tracy Ann Taylor*** (taylorta2@appstate.edu), NC, **Holly Cook**, NC, **Danielle Kane**, IN , and **William C Bauldry** (bauldrywc@bellsouth.net), NC. *Implicit Priorities of College Freshman.* Preliminary report.
We apply the Analytic Hierarchy Process, a technique of Operations Research, to determine implicit priorities of college freshman in what they hope to achieve in their college experience. (Received September 12, 2014)

1106-VC-1795 **Hannah M Pennington*** (hannah.pennington412@topper.wku.edu), **Nitin A Krishna** and **Richard C Schugart**. *Latin hypercube sampling and Partial Rank Correlation Coefficient procedure as applied to a mathematical model for wound healing.*
Latin hypercube sampling and Partial Rank Correlation Coefficient procedure (LHS/PRCC) can be used in combination to perform a sensitivity analysis that assesses a model over a global parameter space. Through this analysis, the uncertainty of the parameters and therefore the variability of the model output in response to this

uncertainty can be observed. Latin hypercube sampling divides the parameter space into equiprobable regions without replacement, producing a global, unbiased selection of parameter values. For monotonic, non-linear relationships, the correlation between the outputs and parameters can be understood by performing a Partial Rank Correlation Coefficient procedure. This sensitivity analysis is applied an ordinary differential equation model describing the interactions of four proteins and cells in the healing of a diabetic foot ulcer. The results of the LHS/PRCC sensitivity analysis are used to assess the biological significance of the parameters in relation to each compartment of the model to further understand its biological implications. (Received September 15, 2014)

1106-VC-2017 **Joseph W. Eyles*** (jeyles@gordonstate.edu). *Tour de Math: Teaching Through the Mathematical Culture of France.* Preliminary report.

From the Pont du Gard to Paris and from aqueduct siphons to CERN, can travel in France give students new perspectives from which to study mathematics? Will dallying among the designs of DaVinci, roaming the ruins of the Roman Empire, surveying the components of an atom-smasher, or looking over the world's most renowned landmark enhance understanding in mathematics? The presenter discusses some uniquely French mathematical experiences that should appeal to students of mathematics and his experiences with American students in France. (Received September 15, 2014)

1106-VC-2033 **Miriam Harris-Botzum*** (mharrisbotzum@lccc.edu), 4525 Education Park Drive, Schnecksville, PA 18069. *The Mathematics of Conflict: Using Statistical Tools to Analyze Military Outcomes and Political Claims.*

In the modern world, wars are sometimes fought as much in the headlines as they are on the front lines. With both sides making conflicting claims about the conduct of the war, can we use statistical hypothesis testing to analyze those claims objectively? This project is designed to be used in an introductory statistics course, but could also be used in a history or political science course, or as a joint project between the two. Students are asked to identify sources of relevant data, evaluate the reliability of that data, and then perform a hypothesis test using that data to test the validity of the claims made by various parties. (Received September 15, 2014)

1106-VC-2334 **Jennifer F. Vasquez*** (jennifer.vasquez@scranton.edu) and **Michael Allocca** (mallocca@muhlenberg.edu). *Combinatorial Rearrangements of Bacterial Genomes via Circular Permutations.* Preliminary report.

In this talk, we will discuss how circular permutations can be used to help understand and model the evolution process of genomes. Specifically, we will discuss an analogue of the classical bubble sort algorithm that can be used to sort circular permutations and thus model rearrangement sequences between similar genomes. (Received September 16, 2014)

1106-VC-2555 **Horia I Petrache*** (hpetrach@iupui.edu), Department of Physics, Indiana Univ. Purdue Univ. Indianapolis, Indianapolis, IN 46202. *Generalized complex numbers and motion in central force fields.* Preliminary report.

Classical physics, mechanics in particular, is done using vector spaces and complex numbers. Recently, multidimensional number systems such as the quaternions are receiving renewed attention due to a more natural way of describing rotations and other symmetry transformations of physical systems. Among multidimensional numbers systems, quaternions (4D), and the 8-dimensional octonions are most widely known in addition to conventional complex numbers in 2D. However, a larger class of multidimensional numbers exists and can be systematically parameterized. I will discuss such parameterizations for small number of dimensions and show examples of using generalized complex numbers to describe trajectories in central force fields. (Received September 16, 2014)

1106-VC-2575 **Emily Hendryx*** (emily.hendryx@rice.edu). *Using Variants of Dynamic Time Warping to Identify ECG Features in Congenital Heart Disease.* Preliminary report.

In the clinical setting, bedside monitors present physicians with large amounts of physiological data. Interpreting the entirety of this information in real time for clinical decision support purposes can prove to be quite a challenge. This work approaches one aspect of this big data problem by detecting features of the electrocardogram (ECG) signal for prediction of cardiac arrest in patients with congenital heart disease. In doing so, variants of the dynamic time warping algorithm are used for comparing segments of ECG time series on a beat-by-beat basis. These methods produce a mapping between the indices of two segments, minimizing the error between the time series and providing a distance measure for use in segment classification. (Received September 16, 2014)

1106-VC-2693 **Samuel Olson*** (samuel.w.olson@my.minotstateu.edu) and **Narayan Thapa** (narayan.thapa@minotstateu.edu). *Stability Analysis of Inverse Modeling Problems in Chemical Kinetics.* Preliminary report.

Studying chemical kinetics using Carbon Dioxide absorption on a Platinum surface as a template is carried out in different inverse modeling techniques. Mechanisms are studied by using a system of ordinary differential equations along with Lavoisier's law of mass conversion. In this talk, we discuss both inverse problem and the associated modeling from theoretical point of view. In addition, we discuss the stability of solution. (Received September 16, 2014)

General Session on Mathematics Education

1106-VD-3 **Rob Eby*** (jeby@blinn.edu). *How to have group exams but an individual final exam for students. A discussion of how this promoted collaborative learning and lead to individual student inquiry in several types of classes.*

Collaborative learning is a hot topic. However, most institutions require an individual final exam for each student. In this session the presenter will share how he had both of these exam types in his several different classes. There will be a brief discussion of what went right and what went wrong, examples of student responses, student perceptions, and some suggestions for those interested in doing this in their own classes. In addition, the presenter will have examples he used in class and if time permits, questions will be taken from the audience. There will also be a website with more information for those interested in trying this in their own classrooms. Example. On the take home part you had:

An average newspaper contains at least 11 pages and at most 82 pages. How many newspapers must be collected to be certain:

(1) that at least two have the same number of pages? Answer 73

(2) that at least three have the same number of pages? Answer 145

(3) that at least four have the same number of pages? Answer 217

Now look at the take home part with answers above. Find a formula to use to make sure that there are at least R papers with the same number of pages, where R could be any positive integer. (Received April 17, 2014)

1106-VD-5 **Soofia Malik*** (smalik2@uwyo.edu), 416 Wyoming Hall, Laramie, WY 82071. *University Students' Attitudes toward Mathematics.*

The present study investigated differences in students' attitudes toward mathematics with respect to students' gender, college-year, major area of study, and residency status. The students were either enrolled in an undergraduate or a graduate program in the spring semester of 2014 in a large doctoral granting university in the Rocky Mountain region of the US. The sample consisted of 51 students who volunteered to participate in this non-experimental survey study. Participants completed attitudes toward mathematics survey that was developed and pilot tested by the researcher. The internal consistency of the survey items were tested using Cronbach's alpha and were found to be extremely reliable. Independent samples t-tests were conducted to see the differences between students' attitudes toward mathematics with respect to their gender, degree-level,major field of study, and residency status. A one-way ANOVA was conducted to examine the difference between students' attitudes toward mathematics and their college-year. This presentation will expand upon the results and future directions for this study. (Received August 12, 2014)

1106-VD-64 **John C. Miller*** (jcmill@mindspring.com), 110 Riverside Dr. #14C, New York, NY 10024. *Improving Flipped Classroom Software.* Preliminary report.

The flipped classroom imposes increased demands on software because a student's first exposure to each new topic or problem type is typically via software without an instructor.

Years ago, publishers abandoned multiple-choice and now accept arbitrary short answers to most problems. Short answer software is widely accepted as "good enough." Yet when grading manually, good instructors still routinely insist on step-by-step solutions to permit optimal feedback. Math practice software for flipped classrooms should also support student entry of step-by-step solutions and provide appropriate help at each step, regardless of method.

This presentation includes examples from several publishers and a demo by the presenter. The demo, which (a) requires Windows, (b) has an idiosyncratic user interface and (c) poses only a limited range of problems, can be freely downloaded although it is not a practical program. Its purpose is simply to model a help-at-every-step approach to problem-solving for both publishers and prospective adopters, especially those anticipating flipped classrooms. (Received June 17, 2014)

1106-VD-76 **Diana S Cheng*** (dcheng@towson.edu), Towson University, Department of Mathematics, 8000 York Road, Towson, MD 21252, and **Nicole Horner**. *Letter Number Substitution Problems for Mathematics Education Majors.*

We show how a letter-number substitution arithmetic problem, "FOUR + ONE = FIVE," in which letters are substituted with digits, can be used with mathematics education students to help them learn about codes in cryptology. Each distinct letter represents a different single-digit number from 0 to 9. A letter standing for the digit zero never starts a number. Each letter represents the face value of the number and is written in the number's place value – for instance, FOUR represents the number computed by F*1000 + O*100 + U*10 + R*1. The Common Core State Standards for Mathematics – both the Standards for Mathematical Practice and Content Standards – which this problem can address will be described. Three algorithms to find the total number of all solutions for this problem will be presented. These algorithms were implemented using programmed Excel spreadsheets. The efficiencies, benefits and drawbacks of these algorithms will be discussed. (Received June 30, 2014)

1106-VD-159 **Jeanne-Marie Linker***, Mathematics Department, Texas State University, 601 University Dr., San Marcos, TX 78666, and **Sonalee Bhattacharyya**, **Nama Namakshi** and **Christina Starkey**. *Using the Coordinate Plane to Connect Algebra and Geometry and Develop Symbol Sense.*

There is great emphasis on the development of number sense in younger students as they begin working with arithmetic operations; it is certainly necessary to develop a parallel "symbol sense" in students of algebra. In addition, mathematics educators call for implementation of tasks that promote reasoning and problem solving by engaging students in solving and discussing tasks that promote mathematical reasoning and problem solving with varied strategies. This presentation will include a discussion of different classroom settings (elementary through college) in which this activity can be implemented and the results observed. Building on experience and prior knowledge, students explore the relationship between a variable, its square, and its reciprocal using similar triangles. The activity's geometric element gives students the opportunity to develop the intuition and symbol sense that will allow them to more effectively utilize these concepts in higher-level mathematics. (Received August 01, 2014)

1106-VD-177 **Jing-Zhong Zhang** and **Shangzhi Li*** (ztong@otterbein.edu), Beihang University, Beijing, Peoples Rep of China, and **Zengxiang Tong**. *A Piece of the Third Generation of Calculus.* Preliminary report.

This talk comes from Dr. Zhang's more than a decade of research on the third generation of calculus. The rigorous calculus is based on ε-δ limit theory, which is very difficult for high school students and college freshmen to understand. Without using limit theory, the third generation of calculus is rigorous, intuitive, and easy understood to high school students. This talk starts with a few examples, introduces concepts of Function A and Function B, and establishes the differential calculus. This talk also illustrates a research in educational mathematics. (Received August 04, 2014)

1106-VD-178 **Jing-Zhong Zhang** and **Zhaochi Zhang*** (ztong@otterbein.edu), Journal of Studies in College Mathematics, Northwestern Polytechnical University, Xian, Peoples Rep of China, and **Shangzhi Li** and **Zengxiang Tong**. *A Note on the Fundamental Theorem of Calculus.* Preliminary report.

This note uses examples to show pitfalls of the Fundamental Theorem of Calculus stated in most current textbooks, proves an extension of FTC, suggests a revision of the statement of the FTC, and raises an open problem in calculus. This talk also illustrates a research in educational mathematics. (Received August 05, 2014)

1106-VD-179 **Jing-Zhong Zhang** and **Xucheng Peng*** (ztong@otterbein.edu), Huazhong Normal University, Wuhan, Peoples Rep of China, and **Shangzhi Li** and **Zengxiang Tong**. *A Gem of New Euclidean Geometry.* Preliminary report.

This talk comes from Dr. Zhang's more than two decades of research on Automated Theorem Proving in Geometry and his New Euclidean Geometry. His Euclidean geometry is built around two area related theorems: Co-side Theorem and Co-angle Theorem, which are simple, intuitive, and extremely powerful. You will be surprised to see how these two theorems make the proofs of some famous geometry theorems unbelievably simple. (Received August 04, 2014)

1106-VD-457 **Natasha E. Gerstenschlager*** (neg2d@mtmail.mtsu.edu), 1301 E. Main Street, Murfreesboro, TN 37132. *Implementing Reform-Oriented Statistics in the Middle Grades: A Case Study.* Preliminary report.

With the adoption of the Common Core State Standards for Mathematics (CCSSM)(CCSSI, 2010), statistics and probability have a more influential role in the middle grades curriculum than in the past. Specifically, sixth-grade now begins middle-school students' formal exposure to and experience with statistics. However, statistics is generally not a priority in teacher preparation programs, and some teachers may not feel prepared to teach statistics as described in the CCSSM. This presentation will demonstrate current results from a dissertation study that will examine a sixth-grade teacher's implementation of a reform-oriented unit in statistics. The purpose of this case study is to identify what the teacher deems as necessary for implementation fidelity for reform-oriented statistics. (Received August 28, 2014)

1106-VD-534 **Sandra Richardson*** (srichardson@vsu.edu). *The Interrelationship of Preservice Elementary Teachers' Beliefs About Rational Numbers.*

There is a pressing need to better prepare teachers to meet the mathematics education needs of the nation's culturally diverse students. To meet this need, research must address: What forms of knowledge and experiences do pre-service teachers need to develop into good mathematics teachers capable of working with diverse populations of students? This study aims to investigate the mathematics beliefs and development of understanding the concept rational numbers through pre-service elementary teachers' emerging pedagogical content knowledge during the course of a semester. A thorough conceptual understanding of rational numbers is pivotal to the success in the teaching of elementary mathematics. Specifically, the objective of the study is: to determine the algebraic beliefs of elementary pre-service teachers (EPSTs) and the relationship between their rational numbers beliefs and pedagogical content knowledge (PCK). The PCK framework lies at the core of bringing together knowledge about pedagogy and content as interconnecting factors affecting the development of effective teaching. (Received September 01, 2014)

1106-VD-548 **Ioannis Souldatos*** (souldaio@udmercy.edu), 4001 W.McNichols Ave, University of Detroit Mercy, Department of Mathematics, Detroit, MI 48221, and **Mustafa Demir**. *When Students Do Their Homework?*

During the Fall semester of 2013 we used the online homework system WebWork to keep track of when students attempted their homework. The results where compared with their performance on the in-class exams. We will present the results of our research. (Received September 02, 2014)

1106-VD-906 **Theodore S. Erickson*** (erickson@wju.edu), Mathematics Department, Wheeling Jesuit University, 316 Washington Avenue, Wheeling, WV 26003. *A Flipped Calculus III class.* Preliminary report.

The multivariable calculus materials by Denis Auroux,et al. from Open Courseware at MIT was an obvious choice for use in a "flipped pedagogy" class. These materials have been available for several years with 50 minute lecture videos but are now broken into short video segments each focusing on one specific topic. Moreover, recitation videos, complete set of notes and exercises are included, so no text is needed.

The classroom setting is also important, so that working groups can easily function. Our principal mathematics classroom is furnished with 6 large conference tables with four swivel office chairs at each table. An Apple TV is connected to a high definition projection camera so a laptop or an iPad can link to the projector using AirPlay. The class time is broken into three segments: first each student writes two important concepts from the videos on the marking board, followed by clarifications of these concepts, and time spent problem solving in students pairs. Preliminary observations reveal a conversational atmosphere and active learning. (Received September 08, 2014)

1106-VD-927 **David Plaxco*** (dplaxco@vt.edu). *John's Lemma: How One Student's Proof Activity Informed his Understanding of Inverse.*

Recent discussions in the field have explored the proofs' explanatory power. Such research, however, focuses on how a written proof might convey explanation. I present a conjecture that individual proof activity (the development of proofs) might, itself, have explanatory power. I then discuss one student's (John's) activity related to proving that the centralizer for a fixed element in a group (the set of elements that commute with the given element) is a subgroup and how this activity informed his understanding of inverse. During an individual interview, John developed a lemma claiming that the left- and right- inverses of an element are the same element, his proof of which contradicted his previous ways of thinking about inverse. I analyzed John's proof activity using Aberdein's (2006) extension of Toulmin's (1979) model for argumentation in order to better organize his activity, which provides an example of how proof activity might itself be explanatory. (Received September 08, 2014)

1106-VD-938 **Joshua B. Wilkerson*** (wilkerson.josh@gmail.com). *Cultivating Mathematical Affections: Re-imagining Research on Affect in Math Education.*

"When am I ever going to use this?" is a common question in mathematics. It is also more typically presented as a statement. It is a statement of frustration. It is the culmination of confusion and stress and typically serves as an exclamation by the student of their withdrawal from the mental activity at hand. I argue that the real question being raised by students is "Why should I *value* this?" We as math educators must do a better job of addressing this non-cognitive question. We need to do a better job of cultivating what I term as mathematical affections.

Affective language permeates national policy documents on the teaching of mathematics as an ideal we should strive to inculcate into students, but there is little discussion on *how* to go about doing this. This talk will examine the specific passages of the policy documents in question, discuss the shortcomings in the current body of research that exists on affect in math education, and outline a new framework (based on recent work in cognitive psychology and contemporary philosophy) for understanding how we might cultivate mathematical affections. Practical classroom resources and exercises will be offered. (Received September 14, 2014)

1106-VD-994 **Melissa A Stoner***, 1101 Camden Ave, Salisbury University, Salisbury, MD 21804. *Calculus for Bio and Medicine: Course and Pedagogy Assessment.* Preliminary report.

We will look at the preliminary results from a comparison study of Calculus I for Biology and Medicine and traditional Calculus I. We will compare the calculus conceptual knowledge gained between the two populations and the impact of the addition of project based learning. (Received September 09, 2014)

1106-VD-1107 **Kyunghee Moon*** (kmoon@westga.edu). *Unraveling Big Ideas Associated with Difficulties in Connecting Representations.* Preliminary report.

This research investigates preservice secondary mathematics teachers' abilities to connect algebraic and graphical representations in algebra problem solving as well as the big ideas that underlie in the teachers' difficulties in connecting these representations. I conduct clinical interviews with 20 preservice secondary teachers and use qualitative methods to analyze the interview data. The results of the research and the implications on teacher education will be shared with the audience in this presentation. (Received September 10, 2014)

1106-VD-1111 **Ryota Matsuura*** (matsuura@stolaf.edu), 1520 St. Olaf Avenue, Northfield, MN 55057. *Budapest Semesters in Mathematics Education: A Study Abroad Program for Pre-Service Secondary Teachers.*

Budapest Semesters in Mathematics Education (BSME) is a semester-long program in Budapest, Hungary, designed for American and Canadian undergraduates interested in teaching middle school or high school mathematics. BSME was conceived by the founders of Budapest Semesters in Mathematics (BSM), and the two programs share a common goal—to provide their participants with an opportunity to experience the mathematical and general culture of Hungary. BSME is specifically intended for students who are not only passionate about mathematics, but also the *teaching* of mathematics.

BSME participants will study the *Hungarian approach* to learning and teaching, in which a strong and explicit emphasis is placed on problem solving, mathematical creativity, and communication. Participants will also form a professional community of teachers, committed to providing such learning experiences to their students, that will extend beyond their time in Budapest.

In this session, I will give an overview of BSME and describe how it could serve the interests and needs of undergraduates interested in teaching. (**Note:** BSME will also have its own exhibit table at the Joint Meetings.) (Received September 10, 2014)

1106-VD-1144 **Daniel Showalter*** (showaltd@ohio.edu), Athens, OH. *Do High School Mathematics Courses Prepare Students for College Placement Tests?*

This presentation reports on a study designed to estimate the causal effect of taking pure mathematics courses in high school on the likelihood of placing out of postsecondary remedial mathematics. A nonparametric variant of propensity score analysis (marginal mean weighting through stratification) was used on a nationally representative dataset to test for a practically significant causal effect in three groups of students: all comparable students, students who were unlikely to take high-level mathematics courses, and students in a range of demographic categories.

The findings suggest that enrollment in high school mathematics courses may not have as strong of an effect on placement out of postsecondary remedial mathematics as typically claimed in the research literature. More generally, the results suggest that hidden selection bias in many previous education studies may have unwittingly masked the inequity in the U.S. education system. (Received September 11, 2014)

1106-VD-1266 **Jing-Zhong Zhang*** (ztong@otterbein.edu), Guangzhou University, Guangzhou, Guangdong , Peoples Rep of China, and **Shangzhi Li** and **Zengxiang Tong**. *Promoting Research in Educational Mathematics.* Preliminary report.

The term Educational Mathematics (EM) was coined by Prof. Jing-Zhong Zhang in 1980s. This talk will address three topics: What is educational mathematics? Why is it important and imperative to promote research in educational mathematics? How to do research in educational mathematics? The idea of educational mathematics stems from the realization that our mathematics has fallen behind many countries in the world. Our math education needs reform. The major problem is that our math education is a mechanical mix up of general mathematics knowledge and general education theory. Our idea is that the math education should emphasize at educational mathematics, and should enhance our teachers' quality through promoting research in educational mathematics. (Received September 11, 2014)

1106-VD-1279 **Julie C Beier*** (beierju@earlham.edu), 801 National Road West, Drawer 138, Richmond, IN 47374, and **Carolyn Yackel**. *Developing Metacognition in Students' Learning of Mathematics.* Preliminary report.

There is significant literature about the ordering in which students acquire certain mathematical concepts, but we instead ask through what stages do students progress as learners of mathematics. In this talk, we share our preliminary levels for student sophistication as mathematical learners and how this information may be utilized to help student growth. Subsequently, we look at rubrics that can be implemented to help students develop metacognition and share initial observations about the success of this tool. (Received September 11, 2014)

1106-VD-1380 **Matt M Bell***, matt.bell@enmu.edu, and **Joan Brown**, joan.brown@enmu.edu. *STEM Bridge Program.*

The STEM Bridge program at Eastern New Mexico University was designed to assist incoming freshman who are interested in STEM fields and who fall just below the minimum placement criteria for college level math. This intense full-day 5 week program strives to fill the Algebra gaps that incoming high school graduates have, train students about metacognition, and engage students in interesting science explorations. The students also engaged in half-day activities that would range from bird watching to chemistry experiments to meeting with offices around campus to familiarize themselves with the campus experience. Full details about the STEM Bridge program will be provided. (Received September 12, 2014)

1106-VD-1422 **Michael A. Tallman*** (michael.tallman@asu.edu), 3411 S Wilson Street, Tempe, AZ 85282. *Characterizing the Pedagogical Utility of a Secondary Teacher's Understanding of Angle Measure.*

This study challenges the assumption that teachers' mathematical knowledge is ready-made to inform their instructional actions. I conducted a teaching experiment to construct a model of a secondary teacher's way of understanding angle measure and examined how the teacher's understanding affords or constrains his capacity to bring this knowledge to bear in the context of teaching. The results suggest that the teacher, David, possessed two complimentary but conceptually distinct ways of understanding. David had not, however, reflected on these understandings in a way that allowed him to become consciously aware of having them. David was therefore unable to strategically employ his two ways of understanding in novel problem solving situations and was unable to leverage his understandings in the context of teaching. (Received September 12, 2014)

1106-VD-1513 **Rebekah B Johnson Yates*** (rebekah.yates@houghton.edu), 1 Willard Ave, Houghton, NY 14744. *The Subspace Game.*

Candy, bonus points, and friendly competition can make practicing even the most basic definition-checking direct proofs more exciting for everyone. In this talk, I will share the game we play in my linear algebra classes to solidify their skills for writing subspace proofs and share ideas for adapting this simple but effective game to other topics in both linear algebra and other courses. (Received September 13, 2014)

1106-VD-1572 **Kevin Murphy*** (kevin.murphy@snc.edu). *Adapting Common Problem Types to Incorporate More Modeling.*

Perhaps the most common question asked in lower level math classes is "When am I ever going to use this?" Too often, these courses focus too heavily on techniques which causes students to lose interest and see mathematics as how to find answers rather than how to think critically. This talk examines typical problem archetypes from Algebra and Precalculus textbooks and discusses methods and strategies for adapting these problems to emphasize a mathematical modeling mindset. (Received September 14, 2014)

1106-VD-1579 **Xiaofen Zhang*** (xzhang2@hotmail.com). *The influence of hands-on activities incorporating different models on student understandings of rational numbers.*

Many students experience difficulty in learning fractions. In order to assist them to grasp the concepts, researchers have placed special emphasis on the need for multiple representations (Dienes, 1960). Dienes claimed the quality of conceptual learning is likely to be maximized when students are exposed to a concept in a variety of different situations represented through different embodiments. Forty elementary students participated in the study, who had been taught fractions concepts mainly through an area-model approach. They were first administered pre-teaching tests and interviews to explore how early experiences of learning fractions affected their thinking with respect to fractions concepts and skills. After their normal math teacher taught them 5 fractions lessons including 6 hands-on activities, they participated in post-teaching tests and interviews. Analysis of pre-teaching data showed the students' understandings of fractions were very shallow and many of them could NOT solve problems where fractions were associated with non-area model representations. Analysis of post-teaching data indicated the intervention lessons not only enabled students to perform well on post-intervention tests, but also helped them develop a more connected understanding of fractions concepts. (Received September 14, 2014)

1106-VD-1617 **Keri A Kornelson*** (kkornelson@ou.edu). *An Inverted Proofs Course.*

We discuss the experience of running a sophomore-level Discrete Mathematics course in an inverted format. The course entailed screencast videos for content delivery and primarily group work during class time. There were hurdles along the way and a steep learning curve, but also resources such as a newly-remodeled classroom with round tables and whiteboard space on all walls. Overall, students learned how to try out ideas, work as a team, and critically examine each others' work. The talk will share some of the successes and challenges that arose during the semester. (Received September 14, 2014)

1106-VD-2074 **Eileen Murray*** (murrayei@mail.montclair.edu), Department of Mathematical Sciences, 1 Normal Ave, Montclair, NJ 07043. *Connecting Secondary and Tertiary Mathematics.* Preliminary report.

In university mathematics departments across the United States, it is an exciting period of innovation and experimentation as mathematicians with interest in secondary education have created a wide array of courses designed specifically for mathematics majors studying to become teachers. The impetus for the increasing number of these connections courses may be a product of research more clearly articulating the need for such knowledge, e.g., pedagogical content knowledge (Shulman, 1986) and mathematical knowledge for teaching (Ball, Thames, & Phelps, 2008). Additionally, the increasing number of productive and sustained collaborations between mathematicians and mathematics educators has resulted in efforts from those in the mathematics community to improve K-12 mathematics education and the policy around mathematics and mathematics teacher education (e.g., MET-II report). This presentation discusses results of an informal survey of the landscape of connections courses and provides descriptions of two types, secondary mathematics from an advanced standpoint and tertiary mathematics with connections. The goal is to urge further development and analysis of connections courses to better understand what might be optimal for prospective teachers. (Received September 15, 2014)

1106-VD-2183 **Osvaldo Daniel Soto*** (osoto@sandi.net), 3763 33rd St, San Diego, CA 92104. *Teacher Change in the Context of a Proof-Centered Professional Development: A Case Study of One Teacher's Proof Schemes.*

As proving is a central activity in the study of mathematics, a teacher's own proof schemes (in the sense of Harel and Sowder, 1998) enable and constrain her instructional approaches. Though it is acknowledged that teachers' knowledge of mathematics is a cornerstone on which their instructional practices are based (e.g., Ball and Bass, 2003), little research exists documenting professional developers' attempts to influence teachers' proof schemes and the results of these attempts. This case study examines the development of one teacher's proof schemes in the context of an NSF funded proof-centered professional development (PD). Specifically, the study asked: What changes were observed in one participant's proving and proof schemes as she participated in the PD? While the study focuses on the developments of one participant's proof scheme, it also describes the rich environment in which the development occurred. It was found that during the two intensive summers of PD, the participant became increasingly able to identify pivotal statements in her own proofs that had previously been left unattended and that the participant showed evidence of a transition from empirical to deductive proof schemes. (Received September 16, 2014)

1106-VD-2297 **Aldo R. Maldonado*** (a.maldonado@park.edu), 15300 Cadoz Dr., Austin, TX 78728. *What is the best way to learn Regression Analysis ?*

Author will discuss how students internalize the concepts related to regression analysis. Many misconceptions are described and lessons learned on what works best will be explained and analyzed. (Received September 16, 2014)

1106-VD-2444 **Sayonita Ghosh Hajra*** (sayonita@math.utah.edu), Department of Mathematics, University of Utah, Salt Lake City, UT 84112. *Equivalent fractions and the importance of whole.*

In this talk, I will present the connection between the meaning of multiplication and division with equivalent fractions. My study shows division is more complex to understand than multiplication conceptually in the construction of equivalent fractions. I will provide some suggestions to improve understanding of students in equivalent fractions. (Received September 16, 2014)

1106-VD-2469 **Jialing Dai*** (jdai@pacific.edu), 3601 Pacific Ave, Stockton, CA 95211. *Impact of Mathematics Teacher's Classroom Discourse on Developing Student's Mathematical Thinking in Elementary School in China.* Preliminary report.

Mathematical problem-solving is the number one curricular goal in both National Council of Teachers of Mathematics (NCTM) in the United States and Ministry of Education (MOE) of China. In fact, problem-solving is one of the five fundamental mathematical processes identified by NCTM (2000). However, MOE not only regards fostering problem-solving ability as a main goal of mathematics education, MOE also stresses that developing students' thinking ability is the core of mathematical ability. As MOE defines problem-solving and reasoning:

Problem-solving: being able to solve mathematical problems occurring in daily life, workplace and in other subject-matters; being able to use mathematical language to express, communicate and form mathematical thinking. (MOE 2000)

It is clear that mathematical language plays an important role in developing student problem-solving and mathematical thinking ability. This talk shares some insights from a qualitative study conducted in a few elementary schools in China on how teacher's classroom discourse promotes students use of appropriate mathematics language to communicate their thinking, and hence facilitates developing student problem-solving skill and mathematical think ability. (Received September 16, 2014)

1106-VD-2480 **Van Herd*** (herd@austin.utexas.edu), College of Undergraduate Studies, University of Texas at Austin, Austin, TX 78712. *Visual Representation in Undergraduate Mathematics Education: Lessons from the Pedagogy of the Sciences.*

Despite technological innovations, the epistemology and practice of undergraduate mathematics education remains unchallenged. Whether the instructor uses the blackboard, the iPad, or a variety of virtual configurations, teaching remains still very much the same as it was in the last century.

Using insights from the emerging field of neurocognition, the author suggests alternatives that he has used in innovating the undergraduate mathematics classroom. The focus of his attention will be a critical analysis of the rhetoric of the standard undergraduate university lecture and the corresponding visual representation of those ideas.

Using examples from his own successes with undergraduate mathematics students, ranging from honors to developmental, the author will present curricular examples as well as neurocognitively grounded examples that are widely used in undergraduate science education that mathematics instructors may wish to import in whole or in part into their undergraduate mathematics instructional sequence. (Received September 16, 2014)

1106-VD-2542 **Matthew S. Winsor*** (mwinsor@ilstu.edu), Department of Mathematics, Campus Box 4520, Normal, IL 61790-4520. *Helping future high school teachers integrate their mathematical and pedagogical knowledge.*

Secondary mathematics teachers must develop a deep and connected understanding of both mathematics and pedagogy in order to interpret student thinking, choose instructional activities, and plan effective lessons. Unfortunately, secondary mathematics majors often do not see the connections between their methods and mathematics courses, creating a disconnect between their pedagogical and mathematical knowledge. To address this challenge, we have designed, implemented, and tested a model of teacher preparation that promotes the integration of mathematics and pedagogy. The model, implemented in a content and methods course taught in tandem, is built on a set of common classroom experiences. These common classroom experiences include mathematical tasks, student work, videos, etc. taken from high school classrooms. By investigating a common experience through both a pedagogical and mathematical lens future teachers will have to chance to not only see the connections between mathematics and pedagogy, but to enact them in instructional settings. The goal of the presentation is to share our model and to promote a discussion regarding strategies for better preparing future secondary teachers to integrate their knowledge of mathematics and pedagogy for the purpose of instruction. (Received September 16, 2014)

1106-VD-2546 **Oscar Chavez*** (oscar.chavez@utsa.edu), Department of Mathematics, One UTSA Circle, San Antonio, TX 78249, and **Ruthmae Sears** (ruthmaesears@usf.edu), Department of Teaching and Learning, College of Education, 4202 E. Fowler Ave., EDU105, Tampa, FL 33620. *Informal and formal proofs in geometry: Evidence from a large scale curriculum comparison study.*

Secondary students have difficulties in constructing proofs. There is variation in the attention to proof given in secondary geometry textbooks, which affects how students learn to prove. In this paper, we examine students' responses to two items in which students had to provide a proof for geometric statements. The first item was designed to elicit an informal argument and was included in a test for first year high school students; the second was a statement about congruent triangles, included in a test that these students took when they were in third year of high school. The tests were part of a longitudinal study on the effect of curriculum choice in U.S. high schools where students could freely choose to study mathematics using one of two types of content organization, an integrated approach or a (traditional) subject-specific approach. The study involved over 2000 high school students in 10 schools in 5 different states. We found that students were more likely to provide correct informal arguments than they were likely to write formal proofs after formal instruction in geometry. We suggest that teachers and curriculum developers should pay more attention to the opportunities they provide students to engage with proof, and the nature of these opportunities. (Received September 16, 2014)

1106-VD-2670 **Carrie Muir*** (carrie.muir@colorado.edu). *Making math your own: a final project for quantitative literacy courses.*

In this talk, I will describe an final project I have assigned in multiple quantitative literacy courses. The goal of the project assignment is for students to connect math to their own interests and passions. The requirements and directions for the project are left non-specific to encourage students to be creative and original with their project. However, students are required to submit progress reports during the semester, and extensive feedback is provided on an individual basis. The final projects are shared with their peers at the end of the term in science-fair style sessions. While students are initially nervous (and sometimes angry) about the open nature of the project, the majority of students create impressive projects, and show great enthusiasm for sharing their creations. The presentation will include examples of student projects from recent classes. (Received September 16, 2014)

1106-VD-2680 **Kathleen D. Lopez***, klopez@louisiana.edu, and **Patricia W. Beaulieu**, pbeaulieu@louisiana.edu. *Louisiana Mathematics Masters in the Middle.* Preliminary report.

Through an NSF Robert Noyce Master Teacher Fellowship grant, faculty members at the University of Louisiana at Lafayette are working with a group of in-service mathematics teachers from three local school districts. The goal is the development of a cadre of master teachers who will become leaders in the middle schools in their districts. These future master teachers have completed over half of the coursework required for newly created Louisiana Elementary Mathematics Specialist Certification and are on track to become the first in the state to obtain this certification. This presentation focuses on the accomplishments and challenges of the first year of this five-year program. (Received September 16, 2014)

1106-VD-2687 **Alexander G. Atwood*** (atwooda@sunysuffolk.edu), 533 College Road, Selden, NY 11784. *Deducing the Age of an Ancient Natural Nuclear Reactor in a Pre-Calculus Class.*

In 1972, French nuclear scientists found that natural uranium in the ore from a mine in Gabon, Africa was slightly depleted in one of the isotopes of uranium, U-235. After careful measurements of the uranium isotopes and the discovery of chemical elements that were nuclear fission products that could have only resulted from uranium fission, it was deduced that a natural nuclear fission reactor was operational approximately 2 Billion years ago in the mine. At that time, the Uranium in this reactor was naturally enriched in Uranium-235 at a level where the reactor could be moderated by ground water flowing through the soil containing the Uranium. By looking at the radioactive decay of Uranium-235 (Half-Life of 0.7 billion years) and of Uranium-238 (Half-Life of 4.5 billion years) and of other radioactive elements created in the reactor, students in a pre-calculus class can calculate the age and operational characteristics of this ancient nuclear reactor. (Received September 16, 2014)

1106-VD-2692 **Laura M. Singletary*** (lsingletary@leeuniversity.edu), 1120 North Ocoee Street, Cleveland, TN. *Teachers' Beliefs about the Connected Nature of Mathematics.*

In this study, my data sources included six in-depth, semi-structured interviews and approximately two weeks of classroom observations for each secondary teacher. I used an inductive and iterative coding process to analyze the classroom data, and I developed a framework to describe the explicit kinds of mathematical connections teachers made in practice. To analyze the teachers' beliefs, I coded the data, drawing upon Green's (1971) metaphorical interpretation of the structure of a belief system and Leatham's (2006) theory of sensible systems of beliefs.

I develop my findings through a series of narrative cases as well as a comparison across the cases. The teachers in this study made various kinds of mathematical connections for and with their students. Examining teachers' beliefs about mathematics provided valuable insights into these teachers' practices, providing an understanding for some of the variation occurring among the mathematical connections the teachers made in practice. The mathematical connections each teacher made in practice were often related to the teacher's beliefs about mathematics and, in particular, the teacher's beliefs about the connected nature of mathematics. (Received September 16, 2014)

1106-VD-2812 **Mike May*** (maymk@slu.edu), Dept of Math and Comp Sci, Saint Louis University, 221 N Grand Blvd, St Louis, MO 63103. *Using WeBWorK for Reading Quizzes to Encourage Reading the Text Before Class.* Preliminary report.

Each day, students were required to answer a WeBWorK question over the reading to be covered in class that day. The question was a multiple select question with between 6 and 10 choices to allow easy construction. The question was due before the start of class each day. The reading quizzes were counted for about 5% of the grade. Using student reporting on evaluations, there was a significant increase in the frequency of how often the students read the book (Received September 16, 2014)

1106-VD-2875 **Elizabeth A Miller*** (elizmiller@math.osu.edu), **Jason A Miller** (millerj@math.osu.edu) and **Carolyn Johns** (johns.125@math.osu.edu). *Orient Students to your Course with a Treasure Hunt.*

Does this sound familiar: "How are we graded in this course?", "How do I register for the online homework system?","How was I supposed to know this was due!" For many math courses, especially first year courses which use technology, students are expected to assimilate a large amount of information about how the course is set up very quickly. As much as we want students to carefully read through the syllabus, they often just skim it. Some don't look at it at all. In order to help address this problem, we have starting using a Treasure Hunt to introduce students to the important information about the course in our online and hybrid courses. The treasure hunt, which is built into our course management system using release conditions, begins with a short video which welcomes students to the course and introduces how the course is set-up. At the end of the video, there is a clue to what students should do next. As the students work through the Treasure Hunt, they learn about each aspect of the course before the next clue is released. From an instructor's prospective, the treasure hunt prepares most students to understand the course format before the first day of class. It also allows early intervention with students who are not on track before they miss a crucial deadline. (Received September 16, 2014)

1106-VD-2913 **Fatma Celiker*** (fatozmat@gmail.com), Yildiz Technical University, Department of Mathematics, Faculty of Art@Sciences, Istanbul, Turkey, **Pinar Albayrak** (pinarkanar@yahoo.com), Yildiz Technical University, Department of Mathematics, Faculty of Art@Sciences, Istanbul, Turkey, and **Sebahat Ebru Das** (ebrudas@gmail.com), Yildiz Technical University, Department of Mathematics, Faculty of Art@Sciences, Istanbul, Turkey. *Potentional Teachers' Sources.*

In this study we compare potentional teachers' sources. (Received September 17, 2014)

General Session on Mathematics and Technology

1106-VE-75 **Razvan Alexandru Mezei*** (razvan.mezei@lr.edu), LRU 7416, Hickory, NC 28603. *Using SAGE Mathematics software in Numerical Analysis courses. It's Free and Easy.*

SAGE is a Mathematical Software that is increasingly being used in several areas of Mathematics and Engineering, such as Linear Algebra, Calculus, Number Theory, Cryptography, Numerical Computation, Group theory, Combinatorics, Graph Theory, and others.

It is a free alternative to Mathematica, Maple, and MATLAB, and it is Python based. Even if the your students don't have any Python background, you should not worry too much: it is one of the easiest programming language to learn.

Students can use a web-based version of SAGE, also called a SAGE Cell server (for example http://sagecell.sagemath.org), or they can download and use it on their own machines. The SAGE Cloud (http://cloud.sagemath.com) is yet another great way to use SAGE, that provides, among others, an environment where students can perform computations, write LaTeX documents, save and share their work, and collaborate with others.

In this presentation, I plan to share some of the tricks and techniques that can be used when teaching a Numerical Analysis course using SAGE.

The ability to use SAGE as a computational tool as well as a tool for creating 2D and 3D graphics will help making your class more interactive, more productive, and more fun. (Received June 29, 2014)

1106-VE-314 **Alexander L. Garron*** (alexander@sandboxgeometry.com), 2502 Park Place, Springfield, NJ 07081. *Using Analytic Geometry and Computer Algebra to Construct Gravity Field Energy Curves.*

I have always been interested in finding a utility for plane geometry to study mechanical energy curves of the gravity field. To do so I invented a Curved Space Division Assembly, acronym CSDA, the parametric graphing assemblage of two plane geometry curves (unit circle as independent curve and unit parabola as dependent curve) that I use to explore mechanical properties of gravity field changing acceleration causality of orbit motion in curved space. To explore mechanical properties of g-field curved space requires a plane geometry construction of Sir Isaac Newton's Inverse Square Law of Gravity to prescribe available energy of the system controlled by M1 producing orbit motion of M2. This paper will use Mathematica to demonstrate high school STEM methods needed to do so. A first ever analytic geometry construction of the connecting principal joining inverse square field properties of curved space with its linear meter primitive radius following orbit motion in physical square space. I will demonstrate means to apply CSDA analytics on mechanical energy curves of our Earth/Moon system proving construction results using Sir Isaac Newton's Universal Law of Gravity. (Received August 21, 2014)

1106-VE-379 **Robert Hunt*** (rhunt@olemiss.edu), The University of Mississippi, Department of Mathematics, 305 Hume Hall, University, MS 38677. *Overcoming the Impact of Reduced Funding Through Course Redesign.*

Between 2008 and 2013 Mississippi higher education funding has been reduced by over 26% per FTE. At the same time, enrollment at the University has increased 42%. In this presentation, the speaker will discuss how the Mathematics Department has overcome funding reductions through redesign with technology and how the lab component has accommodated more students without the increased need for instructors.

The redesign of these courses helps ensure consistency across sections and supports graduate students that are teaching for the first time. Additionally, the course coordinator has more time to address any issues that might arise. Instructors are now able to spend more time teaching and working with students instead of creating assignments or record keeping. Attendance tracking is completely automated as well as grade calculations. The Mathematics Lab component of these courses allows students to receive help much more quickly and easily than having to find time to meet with their instructor.

Information will be presented about the structure of the redesigns and the implementation of technology. Results from the successful redesign and future plans will also be presented. (Received August 26, 2014)

1106-VE-469 **Leon Kaganovskiy*** (leonkag@gmail.com), 1233 E 19, apt 6J, Brooklyn, NY 11230. *Applications of R to Introductory and Intermediate Statistics.*

In this presentation we would like to explore using freely available R Statistics Package to teaching Statistics at various levels to create codes which provide efficient, hands-on Scientific Computing tools to enhance students' learning of Statistics concepts and real world Data Analysis. Among the topics considered are graphical Data Analysis with ggplot2, regression, ANOVA, ANCOVA, repeated measures and mixed design, MANOVA etc... (Received August 29, 2014)

1106-VE-625 **Matthew Leingang*** (leingang@nyu.edu). *Using an online homework system for written homework.* Preliminary report.

Online homework systems provide good practice for repetitive, computation problems. How can we automate collection and grading of written homework problems? Systems are adding features allowing essay questions to be added to homework assignments, and for those essays to be graded by human graders. We will discuss lessons learned from administering written homework over the WebAssign and Sakai systems. (Received September 03, 2014)

1106-VE-796 **Anna Savvopoulou*** (annsavvo@iusb.edu), Department of Mathematical Sciences, 1700 Mishawaka Avenue, South Bend, IN 46615. *Effective ways to use GeoGebra for selected topics in Calculus II.* Preliminary report.

This talk will include GeoGebra demonstrations for selected Calculus II topics. Dynamic applets engage and aid students in their learning of approximate integration and convergence of series. (Received September 06, 2014)

1106-VE-885 **Justin Ryan*** (justin.ryan@oswego.edu), Department of Mathematics, State University of New York at Oswego, 7060 Route 104, Oswego, NY 13126, and **Jack Narayan**. *Enhancing Students' Learning Experiences Through Online Instructional Aids.*

In this paper we discuss how WebAssign can be used to supplement classroom lectures, providing students with a more complete learning experience, and saving time and energy for instructors. WebAssign is a fully customizable online instructional system designed to promote self-remediation among students. It offers many time-saving features for instructors which, when used properly, correlate to higher success and retention rates in students. These features include customizable mini video lessons, immediate homework grading and feedback, step-by-step tutorials, and more. We discuss how these features are utilized in our own classrooms to encourage self-guided learning, and their perceived advantages. We also explore ways of using the data analytics produced by WebAssign to improve in-class instruction and student retention. (Received September 08, 2014)

1106-VE-1078 **Darren A Narayan*** (dansma@rit.edu), School of Mathematical Sciences, Rochester Institute of Technology, Rochester, NY 14623. *Realizing the full potential of online instructional systems.*

Online instructional systems, such as WebAssign, are primarily known as homework grading systems. However, these systems have evolved to provide a plethora of resources such as e-books, interactive and video tutorials, and tools for online course remediation. We will provide innovative ways to engage students in the many features of these systems and offer strategies for integrating them into undergraduate curricula. (Received September 10, 2014)

1106-VE-1529 **Howard Troughton*** (htroughton@babson.edu), 374 Great Road, Unit 12, Acton, MA 01720. *Simulation in the classroom using Excel.*

Simulation is the imitation of real-world systems over time and first requires that a model of the system be developed. Computer technology allows students to perform simulations in real-time within a classroom context. A freshman quantitative methods course at Babson College uses simulations to analyze a variety of business problems, including cost-benefit analysis for a start-up business venture, optimal inventory and ordering levels for a product, and strategies for retirement. Models are developed in Excel and the simulation is run using the Excel Add-in program @Risk, created by Palisade Corporation. This talk will demonstrate how simulation is used in this course by presenting examples. (Received September 13, 2014)

1106-VE-1615 **Caroline Haddad*** (haddad@geneseo.edu), SUNY Geneseo, 1 College Circle, Geneseo, NY 14454. *Creating an Introductory Procedural Programming Course with Mathematical Problem Solving.* Preliminary report.

In the fall of 2010, the President of SUNY Geneseo announced the dissolution of the Computer Science Department. Our mathematics department was then forced to consider what to do about our computing requirement, a single course in procedural programming, or a course in Java that was the introduction to the CS major. Neither course had any pre-requisites.

A colleague and I saw this as an opportunity to improve upon the current requirement, and create an introductory programming course, using Matlab (though any similar language could be used), where the focus was solving math problems. Our motivation was to use procedural programming to reinforce ideas taught in areas, such as Calculus and Linear Algebra, with a numerical perspective, and help our math majors realize that computing is a useful, and frequently necessary tool for all mathematicians. This presentation will discuss the course we created, my first attempt to teach the course in Fall 2013, and my second attempt to teach in the fall 2014. (Received September 14, 2014)

1106-VE-1832 **Peter T. Olszewski*** (pto2@psu.edu), 4205 College Drive, Erie, PA 16563. *Did you do your homework?* Preliminary report.

The mathematics service courses at Penn State Erie, The Behrend College, have faced the challenge of students not completing homework assignments, resulting in poor grades and mid-semester class withdrawal. It is often the case that students will not do homework without an incentive, as evidenced by course evaluations suggesting that homework should count as part of the class grade. In the fall 2014 semester, a pilot program was approved to teach Math 110: Techniques of Calculus I, a terminal mathematics course for our business majors, using online homework software to motivate homework completion. The goal of this pilot study was three-fold: (a) to determine if an online homework software package would help improve student performance, (b) to see if the inclusion of online homework would free class time for the instructor to present material more rigorously along with more applications, and (c) to assess if there would be enough support among faculty and administrators to convert one of our large unoccupied class spaces in the School of Science into a mathematics laboratory geared to facilitate computer-based homework completion. In this talk, I will share my findings, share plans for the future laboratory, and discuss how to most effectively use such a space. (Received September 15, 2014)

1106-VE-2037 **James Cooper*** (james.cooper@reasoningmind.org) and **Paulette N Willis**. *Just because you can, doesn't mean you should.*

Designing good multimedia instruction requires consideration beyond aesthetics. A student user's engagement can be significantly impacted by each design choice, and it may be the case that the aesthetic choice is not the right choice for engagement. Here we discuss certain elements that have been shown to help or hinder engagement and learning. We also discuss the experience of Reasoning Mind in adopting these helpful design elements and the resulting high levels of student engagement. (Received September 15, 2014)

1106-VE-2038 **Paulette N Willis*** (paulette.willis@reasoningmind.org) and **James Cooper**. *Can the measurement of student engagement be automated?*

A good teacher will notice when a student is bored or off task, but as the class size grows so does the difficulty of noticing these things. Structured classroom observation and the use of data-mining algorithms allow one to surmount this issue faced by teachers with large classes. In collaboration with Ryan Baker, Reasoning Mind is developing automated methods in its blended learning system that can detect student affect and provide teachers with a complete picture of their classroom's engagement. We discuss the protocol used by Reasoning Mind and the results achieved. (Received September 15, 2014)

1106-VE-2208 **Philip B Yasskin*** (yasskin@math.tamu.edu), Department of Mathematics, Texas A&M University, 3368 TAMU, College Station, TX 77843-3368, **Douglas B Meade** (meade@mailbox.sc.edu), Department of Mathematics, University of South Carolina, Columbia, SC 29208, **Matthew J Barry** (komputerwiz.matt@gmail.com), Texas Center for Applied Technology, Texas A&M Engineering Experiment Station, College Station, TX 77843, **Don Van Huyck** (don.vanhuyck@tamu.edu), Department of Mathematics, Texas A&M University, 3368 TAMU, College Station, TX 77843-3368, **Dmitriy Shatalov** (dmitriy.vladimirovich.shatalov@gmail.com), Department of Mathematics, Texas A&M University, 3368 TAMU, College Station, TX 77843-3368, **Ethan Corpus** (ecorp99@yahoo.com), Somerville High School, Somerville, TX, **Parth Sarin** (parthsarin@gmail.com), A&M Consolidated High School, College Station, TX , and **Michael Sprintson** (michael.sprintson@gmail.com), A&M Consolidated High School, College Station, TX. *Maplets for Calculus, Present and Future.*

By the date of this talk we may or may not have released version 1.4 of Maplets for Calculus, which is a collection of Maple based applets which tutor students in calculus and related subjects. From 1.3 to 1.4, the number of applets increased from 129 to 201, with the inclusion of many more applets on precalculus, limits, complex numbers, multivariable calculus and differential equations. We also incorporated student and instructor ratings, and the ability to store grades in a database. We will show some of the new maplets and emphasize the rating and grading features. (Received September 16, 2014)

1106-VE-2285 **Jeffery D. Sykes*** (sykesj@obu.edu), Ouachita Baptist University, 410 Ouachita Street, Arkadelphia, AR 71998. *Lessons learned while developing an online, modeling-based College Algebra course.* Preliminary report.

After studying mathematics enrollment patterns at Ouachita Baptist University, the author led an effort to change the focus of the department's College Algebra course from one designed as preparation for Calculus to one focused on problem solving and mathematical modeling. Almost immediately thereafter, the department received a call to develop the College Algebra course for online delivery as part of the University's new online degree programs. In this paper, the author will discuss the motivations for changing the focus of the course, the foundational principles for the course redesign, the development process of the online course, and the lessons learned - both expected and unexpected - along the way. (Received September 16, 2014)

1106-VE-2432 **Eric W Weisstein*** (eww@wolfram.com), Wolfram Research, 100 Trade Center Drive, Champaign, IL 61820-7237. *Using mathematical and computable data in Mathematica 10.*

Starting in Version 6, *Mathematica* has included a set of curated data collections covering mathematical, scientific, geographic, and other domains. More recently, this concept has been greatly enhanced and extended in *Mathematica* 10 with the help of development work done for Wolfram|Alpha.

There are several components to the integration, the first being the extensive augmentation of the set of available data collections. An even greater step forward is the introduction of entity, entity class, property, and related built-in symbols as a means to represent and manipulate computable data in *Mathematica*. Each curated object in an available data set is assigned a domain (e.g., "PlaneCurve") and a canonical name (e.g., "Ellipse"). Using this framework, objects and their properties can be easily accessed and used directly in computations.

Mathematica 10 also provides a number of convenient ways to discover computable data, the most powerful being a revamped implementation of "free-form input." The resulting synthesis of data representation, exposure, and access provides a powerful, flexible, and extensible framework which is practically and usefully applicable to mathematics or virtually any other domain of interest. (Received September 16, 2014)

1106-VE-2760 **Amanda Hattaway*** (hattawaya@wit.edu), Department of Applied Math, 550 Huntington Avenue, Boston, MA 02115, and **James McCusker**, **Gloria Ma** and **Stephen Chomyszak**. *Teaching MATLAB Programing to First Year Engineering Students.* Preliminary report.

At Wentworth Institute of Technology, several engineering first year undergraduate student majors take an introductory engineering course in which they are exposed to "laboratory" modules of MATLAB, Solidworks, Innovation in Design, and Manufacturing. In the past, this course was only offered to students in the electrical and mechanical engineering disciplines, and it was only taught by engineering faculty from these two disciplines. In contrast, now, the majority of our engineering students take this course and the faculty teaching team consists of both engineering and math professors. In our presentation, we will report on and share: 1) the materials we developed for MATLAB; 2) collaboration tools that the faculty instruction team and the students used and 3) preliminary results on the impact of this course on our first- and second-year math courses and 4) the impact of this course on our students and faculty. (Received September 16, 2014)

1106-VE-2936 **Mel Henriksen*** (henriksenm@wit.edu). *Using an Online "Clicker" Application to Promote Student Engagement in a Differential Calculus Course.* Preliminary report.

Frequent formative assessment has been reported to have a positive impact on student learning and retention. In recent years such assessment has been done with dedicated hardware "clickers" allowing students to submit solutions to problems from their seats in class. However, either each student must be provided with their own clicker or the instructor must distribute clickers to each class, incurring a purchase cost and a time cost. Through the use of a free, online clicker app, students can use any web-enabled device (smartphone, tablet or PC) as a clicker. The instructor can upload assessments that are then initiated in class. The students' input is recorded and may then be downloaded to a spreadsheet or displayed as a histogram to initiate class discussion. For multiple choice questions the student receives immediate feedback. Instructors can write their problems using text, or more complicated math notation may be written and uploaded as an image. We use this technique to provide quick in-class assessments at the end of each topic covered. After an initial familiarization period we hope that this technique will become a fluid and seamless part of the week's instruction. (Received September 17, 2014)

General Session on Mentoring

1106-VF-53 **Sue Brown*** (browns@uhcl.edu). *Mentoring New University Faculty.*

New faculty attend an orientation meeting the week before classes begin where they are introduced to procedures that will help navigate the first few months of the semester. The Mentoring Committee sponsors four luncheons that focus on: research, the annual review process, teaching, and mentoring evaluation and feedback. In the spring, each new faculty member meets with the Associate Dean and department chair where the faculty's progress toward tenure is discussed and an action plan is formulated for the next year. Each faculty completes a third year review, which includes a portfolio. The promotion and tenure committee,the AD,and the Dean review the portfolio and submit review letters. Following the receipt of these letters, the faculty member meets with the Dean, AD, department chair,and chair of the P&T committee. These individuals summarize the faculty's progress toward tenure in the areas of teaching, research, and service. The following semester,the faculty receives a one-course reduction in teaching load to focus on the issues raised in the third year review.In the tenure portfolio, faculty are required to document how they addressed the tenure recommendations from the third year review process. (Received June 02, 2014)

1106-VF-185 **Noureen Khan***, 7300 Houston School Rd., Dallas, TX 75241. *Intentional Mentoring.*
As a mentor, faculty member can make a life long impact on her students. However, providing quality mentorship to undergraduate research students has recently emerged as an important strategy for successfully recruiting and retaining students in the mathematics programs. We explore the value of mentoring, the developmental pro file of young mathematicians, and the traits of a good mentor. (Received August 06, 2014)

1106-VF-316 **David Hartenstine*** (david.hartenstine@wwu.edu) and **Perry Fizzano**. *Mentoring in a Scholarship Program for Distinguished Undergraduate Women in Computer Science and Mathematics.*
Mentoring, both formal and informal, is critical to the success of the CS/M Scholars Program at Western Washington University. The ultimate goal of this program, now in its fourth year, is to graduate more women in computer science and mathematics. It is funded by the NSF's S-STEM program. Various forms of mentoring and their importance to overall program goals will be discussed. These include: early and ongoing advising by departmental faculty and staff, peer advising, cohort creation and preservation, student involvement in recruitment and retention, and networking with upperclassmen, alumni and working professionals. The effectiveness of these activities is supported by survey results, institutional data and anecdotal evidence. (Received August 21, 2014)

1106-VF-599 **Karoline M Auby*** (kauby@uwlax.edu), 1725 State Street, La Crosse, WI 54601, and **Robert Hoar** (rhoar@uwlax.edu), 1725 State Street, La Crosse, WI 54601. *ICE (Institute for Campus Excellence) and Faculty On-boarding.*
UW-La Crosse has developed an Institute for Campus Excellence and an ongoing process for new faculty on-boarding. The new ICE space is a set of technology enabled rooms and is the physical manifestation of the new faculty on-boarding effort. The Institute offers UW-La Crosse faculty and staff a space to come together to discuss what they do, share and explore new concepts, and learn about new methods and resources related to teaching and research.

In addition to the space, the university has revised the new faculty orientation, the new faculty handbook, and the methods by which the information is distributed. A two-day orientation program is held to introduce the faculty to important information they need to know before classes begin (i.e. general education requirements, syllabus requirements, etc.). A new handbook has been developed to provide a single location to find information relevant to various aspects of their new position.

We will discuss unique features of these new efforts and discuss how they are supporting faculty retention and promotion. (Received September 03, 2014)

1106-VF-959 **Jenna P. Carpenter*** (jenna@latech.edu), PO Box 10348, Ruston, LA 71272. *Navigating Worklife Policies: Best Practices for Faculty and Departments.*
For the last five years, Louisiana Tech University has had an NSF ADVANCE Project designed to create a culture of success for women faculty in mathematics, science and engineering. One of the focus areas has been to develop and implement worklife policies for all faculty which better support their success. Here we look at best practices associated with developing and implementing such policies, focusing on faculty, administrators and departments, and informed by our own experiences in this arena. (Received September 09, 2014)

1106-VF-1315 **Kate G. McGivney*** (kgmcgi@ship.edu) and **Sarah N. Bryant**. *Recruiting, Retaining, and Advancing Female STEM Faculty at Teaching Institutions.*
STEM-UP PA, a University Partnership for the Advancement of Academic Women in STEM, is a regional partnership between Shippensburg University, Elizabethtown College, Harrisburg University of Science and Technology, and the Innovation Transfer Network whose goal is to support the recruitment, retention, and advancement of academic faculty women in STEM fields. This grant-funded partnership (NSF ADVANCE PAID grant 1107082) uses a broad platform for developing and delivering mentoring programs and other support to campuses across a large region, thereby reducing faculty isolation. In this talk we will present several lessons learned over three years of implementing high-impact practices that support faculty women at teaching-focused institutions. We will highlight experiences in mentoring and faculty development aimed at recruiting and maintaining a diverse STEM faculty body. (Received September 12, 2014)

1106-VF-1945 **Stacey Muir*** (stacey.muir@scranton.edu), University of Scranton, Mathematics Department, Scranton, PA 18510, and **Stephanie Edwards**, **Shannon Overbay** and **Rebecca Wahl**. *Peer Mentoring Alliances: Supporting Female STEM Faculty at Primarily Undergraduate Institutions.*

The NSF ADVANCE initiative strives to increase the participation and advancement of women in STEM disciplines. We will describe one such funded proposal called ASAP (Advancing women in STEM disciplines At Primarily undergraduate institutions) that uses mentoring alliances as the critical pillar. Sixty seven women, including fifteen mathematicians are actively participating in this five year program. We will discuss the structure and the mentoring aspects, as well as the benefits that have already been gained through participation. (Received September 15, 2014)

1106-VF-2511 **Jessica L Spott*** (jessica.spott@ttu.edu), Box 41042: Math Department, Texas Tech University, Lubbock, TX 79409-1042. *Student and Faculty Mentoring Through the Texas Tech Proactive Recruitment in Introductory Science and Mathematics (PRISM) Scholars Program.*

This presentation will discuss the student and faculty mentoring relationships in the Proactive Recruitment in Introductory Science and Mathematics (PRISM) Scholars Program funded by the National Science Foundation at Texas Tech University. Scholars participating in the program are underrepresented students interested in pursuing math and science degrees at Texas Tech. These students participate in undergraduate research with faculty members throughout the year, while experiencing research in various areas in math and biology during summer guided research experiences. (Received September 16, 2014)

General Session on Modeling or Applications

1106-VG-436 **Danielle Burton*** (dburton3@utk.edu) and **Shandelle M Henson**. *A note on the onset of synchrony in avian ovulation cycles.*

Spontaneous oscillator synchrony occurs when populations of interacting oscillators begin cycling together in the absence of environmental forcing. Synchrony has been documented in many physical and biological systems, including estrous/menstrual cycles in rats and humans. In previous work we showed that Glaucous-winged Gulls (*Larus glaucescens*) can lay eggs synchronously on an every-other-day schedule, and that synchrony increases with colony density. Here we pose a discrete-time model of avian ovulation to study the dynamics of synchronization. We prove the existence and uniqueness of an equilibrium solution which bifurcates to increasingly synchronous cycles as colony density increases. (Received August 28, 2014)

1106-VG-500 **Ellina Grigorieva*** (egrigorieva@twu.edu), 1200 Frame Street, MCL423, math department, Denton, TX 76204, and **Evgenii Khailov**. *Epidemic Modeling and Control.*

The term control is in wide use in the mathematical epidemiology. It is usually assumed that the spread of epidemics is stopped if the basic reproduction ratio is less than 1. There are some papers in which an epidemic control means finding such parameters or initial conditions of the model at which the number of suspected individuals is reduced (for example, by imposing total vaccination) or if the transmission rate becomes very small (washing hands, isolating sick people, closing public events). This approach is very attractive by its simplicity. Unfortunately, there is no proof that such control policy is optimal or even unique. In this paper, for a SIR model with varying population size, we solve an optimal control problem associated with vaccination, treatment and a proper usage of indirect epidemiological measures. Our goal is to find such optimal policy that would minimize the number of the infected individuals at the terminal time. We considered such values of the model' parameters (1947 New York smallpox epidemic), for which the optimal controls, defined from the maximum principle, are bang-bang, with no singular arcs. Estimating the number of switchings of these controls is related to the estimation of the number of zeros of the corresponding switching functions. (Received August 31, 2014)

1106-VG-567 **Elisha D Hall*** (ehall15@my.apsu.edu) and **Ramanjit K. Sahi**. *Applications of SIR-type models in kudzu growth.* Preliminary report.

SIR-type compartmental models have been used in modeling epidemics such as Malaria and Ebola since W.O. Kermack and A.G. McKendrick introduced the concept in the early 1927. Mathematicians use these models to find the rate at which the disease spreads, at what point it becomes an epidemic and what factors are most prevalent in eradication or maintenance of the disease. I will use this same SIR-type compartmental model to demonstrate the interaction between kudzu, an invasive species in Tennessee, to two native flora species. This information will show the rates of growth and decline, the relationship in lifecycles between the plants and the major factors in kudzu control. (Received September 02, 2014)

1106-VG-629 **Melissa R. Adkins*** (swager@math.colostate.edu) and **Yongcheng Zhou**. *Modeling Local Pattern Formation on Membrane Surfaces using Non-local Interactions.* Preliminary report.

The cell membrane is of utmost importance in the transportation of nutrients and signals to the cell which are needed for survival. The magnitude of this is the inspiration for our study of the lipid bilayer which forms the cell membrane. It's been recently accepted that the lipid bilayer consists of lipid micro-domains (lipid rafts), as opposed to freely moving lipids. We present a lipid raft model using the Cahn-Hilliard equations with electrostatics to describe the local pattern formation of these lipid rafts. (Received September 03, 2014)

1106-VG-713 **Kun Gou*** (kgou@msu.edu), Michigan State University, Department of Mechanical Engineering, East Lansing, MI 48824, and **Thomas J Pence**, Michigan State University, Department of Mechanical Engineering, East Lansing, MI 48824. *Modeling of human airway swelling by continuum mechanics.*

Tracheal swelling caused by angioedema refers to the rapid swelling of tracheal tissue by excess accumulation of fluid from vascular leakage, which can be life threatening if it narrows airway rapidly. We present a bio-mechanical analysis with a swelling dependent natural configuration to reflect the altered tissue volume increment under angioedema. Various localized swelling and far field boundary conditions are studied in order to assess how the interaction between swelling, anisotropy and large deformation affects airway constriction. (Received September 05, 2014)

1106-VG-716 **Matthew D Johnston*** (mjohnston@wisc.edu), Department of Mathematics, University of Wisconsin-Madison, 480 Lincoln Drive, Madison, WI 53706. *Correspondence of regular and generalized mass action systems.*

Biochemical reaction networks are often extraordinary complicated, with hundreds of reactions and unknown rate kinetics. Mathematical tools are needed are which can cut through this complexity and give results which are robust to unknown kinetic parameters. In this talk, we consider the dynamical properties of mass action systems which fall outside the scope of established results in chemical reaction network theory, but for which a correspondence can be made to a related generalized mass action system. The constructed generalized system contains different reaction kinetics than implied by the chemistry of the system, but has a strongly connected reaction graph. This approach has proven particularly effective at characterizing the steady states of biochemical networks such as MAPK cascades and signaling processes. (Received September 05, 2014)

1106-VG-782 **Jean-Jacques Kengwoung-Keumo*** (jkengwou@cameron.edu), 2800 West Gore Boulevard, Lawton, OK 73505. *Disparities analysis in cervical cancer between White and African American/Black women using a longitudinal hyperbolastic mixed-effects model.*

With proper screening and early intervention, cervical cancer, caused by infection with particular types of human papillomavirus (HPV), is a highly treatable disease. Because of the screening process and the long period for cancer development, it is also generally preventable. Mortality rates, which have been steadily decreasing with the advent of improved treatment/screening methods, provide a measure of the success in the treatment and/or screening modalities of cervical cancer. In this talk, we model and analyze the disparity in cervical cancer between White and African American/Black women residing in 13 states located in the eastern half of the United States of America from 1975 through 2010. A longitudinal hyperbolastic mixed-effects type II model was used to study the cervical cancer mortality data, and SAS PROC NLMIXED and Mathematica were utilized to perform the computations. In all 13 states, cervical cancer mortality rates for both racial groups have fallen. Disparities in the pace of decline in mortality rates in these states may be due to differences in the rates of screening for cervical cancers. Of note, the gap in cervical cancer mortality rates between African American/Black women and White women is narrowing. (Received September 14, 2014)

1106-VG-945 **Brian J. Winkel*** (brianwinkel@simiode.org). *Using Modeling to Motivate and Drive Learning in Differential Equations Courses.*

Application and modeling are beyond manipulation and solving in a differential equations course. We use modeling scenarios to drive the learning and to introduce the mathematical concepts and techniques in a collegial learning community called SIMIODE - Systemic Initiative for Modeling Investigations and Opportunities with Differential Equations found at www.simiode.org. We give examples of modeling scenarios with data to motivate the study of differential equations. (Received September 09, 2014)

1106-VG-989 **Brittney Hinds*** (s-bhinds1@math.unl.edu). *A Game-Theoretic Approach to Protein Clustering.* Preliminary report.

Protein sequences often include multiple conserved domains. Multiple evolutionary events including duplication, loss, recombination, and divergence generate complex proteins. As a consequence of their complex evolutionary history, a large variation exists in the numbers, types, combinations, and orders of domains among member proteins from the same family, and their evolutionary history is best modeled through networks that incorporate the entire domain content of the proteins. In this talk we propose a game-theoretic approach to constructing biological networks. In this study we examine the application of that approach to classifying multidomain proteins. We applied this method to clustering several sets of simulated protein families, a real multidomain protein family, Regulator of G-Protein Signaling family, as well as entire proteomes. We compare our classification results with the results from several other existing methods, including Markov clustering, protein-domain biclustering, and phylogenetic analysis. (Received September 09, 2014)

1106-VG-1013 **Aisha Najera Chesler*** (aisha.najera@cgu.edu), Claremont Graduate University, Claremont, CA 91711, and **Ami E Radunskaya**, Pomona College, Claremont, CA 91711. *Modeling fetal heart and brain activity during labor.* Preliminary report.

During labor, continuous fetal heart rate (FHR) monitoring is not a reliable predictor for fetal distress caused by severe acidemia. To address this, we present a mathematical model which explores the monitoring of two signals, FHR and electroencephalogram (EEG). The model includes blood flow to the heart and brain and incorporates several key features, such as oxygen delivery to the brain, blood flow redistribution, blood pressure, chemo and baro-receptor mechanisms, all of which affect FHR and EEG. The model can be used to explore features of both signals that are important in detecting fetal distress during cord occlusions of variable intensity, duration and frequency. (Received September 09, 2014)

1106-VG-1198 **William P Fox*** (wpfox@nps.edu). *Applying the common sense test as a diagnostic in mathematical modeling for decision making or research.*

Mathematical modeling is performed often in both decision making and research. We present some examples of mathematical modeling to illustrate (1) when "common sense" must prevail over other diagnostics (2) when using the correct modeling technique and formulation leads to a better "common sense" result, and (3) when you do not have the proper tool available for a quick model. (Received September 11, 2014)

1106-VG-1233 **H Wang*** (hwang@gerorgiasouthern.edu) and **G Peng**, gpeng@mdanderson.org. *Mathematical model of dynamic protein interactions regulating protein stability of tumor suppressors.*

In the field of cancer biology, numerous genes or proteins form extremely complex regulatory network. Many key tumor suppressors such as p53 are regulated through protein stability control, which determines cancer cell fate and cancer cell survival. It remains elusive how we could understand and target p53 stabilization process through network analysis of hundreds of molecules and signals, which are known involved in regulating p53 protein stability. In this presentation we discuss the use of random walk and stationary distribution to measure the compound effect of a network of genes or proteins. This method is applied to the network of nine proteins that influence the protein stability of p53 via regulating the interaction between p53 and its regulator MDM2. This work shows the importance of using mathematical analysis to dissect the complexity of biology networks in cancer. (Received September 11, 2014)

1106-VG-1324 **Andrew S. Brandon*** (asbrando@math.umd.edu) and **Ramagopal Ananth**. *Modeling Local Drainage within an Emulsion using the Arbitrary Lagrangian Eulerian Method.*

Liquid drainage in emulsions and foams is a multi-scale, multi-dimensional phenomena that is tied directly to how an emulsion or a foam behaves. For example, the amount of liquid within an aqueous fire fighting foam determines how effective it is at extinguishing a fire and whether or not the foam will behave as a non-Newtonian fluid. Liquid drainage is driven by gravity and is governed by the liquids' densities and viscosities. There are numerous global, one dimensional, single phase models that can approximate liquid drainage but there are few multi-dimensional models that can be used to study local phenomena. In this presentation, I will discuss a two dimensional, Arbitrary Lagrangian Eulerian (ALE) model that is being used to study local liquid drainage. This discussion will center around the model assumptions, the novel aspects of the algorithm, and recent results. (Received September 12, 2014)

1106-VG-1392 **Sean F. Ellermeyer*** (sellerme@kennesaw.edu), Department of Mathematics, MD 1601, Kennesaw State University, Kennesaw, GA 30144, and **Jesse A. Schwartz** (jschwar7@kennesaw.edu), Department of Economics, Kennesaw State University, Kennesaw, GA 30144. *Optimal Pricing Plans for Auction Houses.* Preliminary report.

We consider the problem faced by a monopoly auction house in developing a pricing plan for its clients (sellers) that will maximize the auction house's revenue. Some typical pricing plans used by auction houses such as ebay include 1) a listing fee (calculated based on the seller's chosen reserve price and paid by the seller whether or not the item sells at auction), 2) a reserve price fee (calculated based on the reserve price and paid only if the item sells), 3) a selling price fee (calculated based on the final selling price of the item) or some combination of these three pricing methods. By employing the powerful theory of optimal mechanism design for sellers and mediators developed by Myerson (1981) and Myerson and Satterthwaite (1983), we obtain several auction house pricing plans that are optimal for English (ascending price) auctions. (Received September 12, 2014)

1106-VG-1543 **Boniface Otieno Kwach*** (bkwach@kibabiiuniversity.ac.ke), Kibabii University College, P. O. Box 1699, Bungoma, Bungoma, 50200, Kenya, **Naphtali Omolo Ongati** (nomoloongati@gmail.com), JOOUST, P. O. Box 210, Bondo, Kisumu, +254, Kenya, **Michael Oduor Okoya** (oduor_okoya@yahoo.com), JOOUST, P. O. Box 210, Bondo, Kisumu, +254, Kenya, and **Amos E. O Otedo** (otedoamos@yahoo.com), Kisumu East District Hospital, P. O. Box, P.O.Box 4685-40103, Kisumu, +254, Kenya. *Mathematical modeling of Insulin therapy in Patients with Diabetes Mellitus.* Preliminary report.

This paper presents a Mathematical Model of Insulin Therapy in Patients with Diabetes Mellitus which includes external rate at which blood Glucose, Insulin and Epinephrine are being increased in the form, $\dot{Y} = AY + \vec{r}(t)$ and whose solution was analyzed to provide the systems natural frequency, ω_0, which is the basic descriptor of saturation level of the drug. It was established that the resonance period for the final model, that is, $T_0 = 3.76912$ hrs, is in the acceptable therapeutic range and agrees well with the data for the existing Insulin therapy. By employing the model, it is shown that, the peak, which is the time period for Insulin to be most effective in lowering blood sugar, is shorter than $T_0 = 5.3199$ hrs, for the existing model. This model would help the medical practitioners to predict Insulin Therapy in patients with Diabetes Mellitus, in such a way that the concentration of the drug remains in the therapeutic range.
(Received September 15, 2014)

1106-VG-1602 **Chris Thron*** (thron@tamuct.edu), Chris Thron, Department of Mathematics, Warrior Hall, TAMU-CT, Killeen, TX 76549. *Increasing prosperity, decreasing satisfaction: insights from an agent-based model.*

Sociological surveys have shown that in many instances, increases in a society's material prosperity have been accompanied by either no change or slight decreases in self-reported well-being. In this paper we present a simple heuristic, agent-based mathematical model of the well-being of individuals in a population, which explains these trends. The model predicts that when individuals' lifestyle choices are biased due to comparison with others (a factor which we call "envy"), then as a result the average well-being of the overall population may experience enormous declines. The net effect can be surprisingly large even when the bias is quite small. Furthermore, even individuals in the population that are not envious end up shifting the balance in their lifestyles towards "conspicuous consumption" at the expense of to less tangible contributions to well-being. (Received September 14, 2014)

1106-VG-1638 **Brendan C. Fry*** (bfry@math.duke.edu). *Effect of structural organization of the kidney medulla on oxygen transport: A mathematical model.*

A theoretical model is presented to analyze the impact on oxygen distribution of the heterogeneous organization of the rat kidney medulla revealed in anatomical studies. Model PDEs are based on active and passive transmural transport processes, as well as conservation of water and solutes (NaCl, urea, O_2, HbO_2, Hb), and are solved to steady state. Results of the model suggest that the structural organization of the renal medulla produces marked axial and radial tissue PO_2 gradients. In addition, the heterogeneous structure preserves oxygen delivery deep into the kidney, but significantly increases the likelihood of O_2-limiting tissue injury. (Received September 14, 2014)

1106-VG-1677 **Richard Vasques*** (richard.vasques@fulbrightmail.org). *Stochastic Transport Theory and Applications.*

In this work we examine the mathematical modeling of subatomic particles interacting with a random background medium, motivated by important applications in the fields of nuclear medicine, atmospherical sciences, and reactor physics. We describe some of the approaches that are currently used to tackle these problems, and present the mathematical tools that model the physical processes taking place. Finally, we discuss the range of topics in this area that are appropriate for undergraduate (and masters level) research. (Received September 14, 2014)

1106-VG-1700 **Yusuf Sofuoglu*** (ysofuoglu@ankara.edu.tr) and **Nuri Ozalp**. *Fractional order bilingualism model without conversion from dominant unilingual group to bilingual group.*

A fractional order model of a population with one bilingual and two unilingual components, in which conversion from dominant unilingual to bilingual doesn't exist is studied. Equilibrium points are found, criteria for the existence and the stability of the positive equilibrium are then investigated. Also, numerical solutions for an example of the fractional order system are obtained by transforming the fractional system to the corresponding integer order one. (Received September 15, 2014)

1106-VG-1817 **Jacquelyn L Rische*** (rische@hws.edu) and **Natalia L Komarova**. *Restructuring of Languages by Learners: a Mathematical Framework.* Preliminary report.

E. L. Newport and colleagues have shown that adults have the ability to restructure linguistic input to facilitate better communication. In Fedzechkina et al. (2012), when learning an artificial language with inefficient case marking, the learners restructure their input to make the case marking more efficient, thus making the language easer to understand. We focus on a variant of our algorithm created in Rische and Komarova (2014) that models the patterns in Fedzechkina et al. (2012). In the study, there are four sentence types, each with different degrees of ambiguity. The meaning of an ambiguous sentence becomes clear when it is case-marked. Our learning algorithm is asymmetric, and we find that the learners (who are all adults) react more strongly to implicit negative feedback. Also, the learners do not remember everything they learn. They forget a certain amount between each day of the experiment. In particular they forget more after the first day since what they learn is not reinforced with a test at the end of the first day (as it is at the end of each subsequent day). With these factors, the learners are able to restructure their input and make the language more efficient. (Received September 15, 2014)

1106-VG-1926 **Vahid Anvari*** (anvari@math.usask.ca), 106 Wiggins Road, Saskatoon, SK S7N5E6, Canada. *Motion Tracking Simulations in Health Training.* Preliminary report.

Motion tracking or motion capture started as a photogrammetric analysis tool in biomechanics research in the 1970s and 1980s. This procedure involves sensing, digitizing, and recording the object in motion and is a collection of techniques and methodologies to attain automatically the motion of the objects of interest. The Motion tracking has been used in various fields such as robotics, military, entertainment, sports, robotics for surgery and biometric applications. In general a study of human's body or in other words human dynamics falls into two categories as follows 1) Tracking, this part includes articulated motion, full body human motion analysis, 3D pose estimation and gait and gesture recognition and 2) Human body motion analysis, which is mainly focused on tracking heads/faces, tracking hands, and tracking human body/bodies. The talk includes a brief discretion of: sensors and their requirements (both hardware/software, and user friendly aspects) for health training purposes; data recording and collection converting the database to management information system (MIS); designing a dynamic modeling system to perform simulation and measure the performance; testing, monitoring and control modules. (Received September 15, 2014)

1106-VG-1952 **Benjamin Jackson*** (jackson@math.montana.edu), Montana State University, Department of Mathematical Sciences, 2-214 Wilson Hall, Bozeman, MT 59717-2400, and **James Connolly**, **Albert Parker**, **Isaac Klapper** and **Robin Gerlach**. *Estimating Parameters in a Bacterial Community Using Inverse Methods.* Preliminary report.

Microbially induced calcite precipitation (MICP) has potential applications in subsurface engineering. MICP takes place in complex systems which often contain communities of bacteria adhering to surfaces, called biofilms, in which mineralization rates are not well known. We seek to characterize these rates in a biofilm system by parameterizing a mathematical model using data from tube reactor experiments conducted at Montana State University's Center for Biofilm Engineering. We formulate a forward ODE model and then solve the inverse problem using basic Bayesian methods. Careful use of synthetic data demonstrates the validity of this approach which we then apply to lab data. (Received September 15, 2014)

1106-VG-2067 **Arturo Vargas*** (av29@rice.edu), 6100 Main St, Houston, TX 77005. *Parameterized Spatial Transformations for Block Match based Medical Image Registration.*

The *Mi*nimal ℓ_1 Perturbati*o*n to Block Match Data (MILO) algorithm is a spatially accurate image registration algorithm developed for thoracic CT inhale/exhale images. The algorithm is based on three components, a

Mutual Minimizing Block Matching Algorithm (MMBM), an ℓ_1 filtering step and recovering a full parameterization based on filtered data points. The algorithm has achieved high spatial accuracy despite a few drawbacks. In order to take advantage of the scattered nature of MMBM data I use a 2^d tree data structure to spatially partition the data. Radial basis functions are then centered over each leaf of the 2^d tree, thereby adaptively partitioning MMBM data. Traditionally MILO has used a uniform B-Spline parameterization. As such, it requires data defined throughout the mesh, something that is not always guaranteed with MMBM data. Furthermore, by modeling voxel displacements as quadratic functions of time I am able to extend the MILO algorithm to multiple images as opposed the traditional modeling that is limited to pairs of images. (Received September 15, 2014)

1106-VG-2083 **Nitin A Krishna*** (nitin.krishna@live.com), **Hannah M Pennington** and **Richard C Schugart**. *On the practical identifiability of a mathematical model for the interactions of matrix metalloproteinases and their inhibitors in a wound.*

We formulate, quantify, and analyze a mathematical model for the interactions of proteins and cells in the healing of a diabetic foot ulcer. Experimental data for modeling were provided by Muller et al. (2008), a research outcome that collected protein and wound closure data for two patient subgroups: "good healers" and "poor healers", where classification was based on the rate of ulcer healing. Estimation of model parameters for the two patient subgroups is done in the context of ordinary least squares. However, especially in complex models with sparse data, several sets of parameters may correspond to the same model state. To assess parameter identifiability, we conduct two sensitivity analyses. A classical sensitivity analysis identified and ranked a set of sensitive parameters, while a subset selection used singular value decomposition followed by QR factorization to give a set of parameters sensitive as a group. Results from the classical sensitivity analysis are used in conjunction with the subset selection to determine identifiable parameters. The developed model has clinical applications, such as determining the biological differences between good and poor healers and implementing a personalized approach to diagnosis using model predictability. (Received September 15, 2014)

1106-VG-2108 **J. Christopher Tweddle*** (ctweddle@govst.edu), 1 University Parkway, University Park, IL 60484. *Maximum entropy modeling of plant biodiversity.*

Maximum entropy methods are a standard tool in the statistical mechanics study of thermodynamics. Recently these methods have been adopted by ecologist to study biodiversity. This talk will present a brief overview of the methodology and how it may be applied to ecological modeling. Preliminary results modeling the plant species diversity of Illinois prairie land will be presented. In particular, the model will be used to predict the relative abundance of plant species in reclaimed prairie lands as a function of plant traits. (Received September 15, 2014)

1106-VG-2225 **Matthew R. Cessna*** (matthew.cessna@cgu.edu). *Effects of the Lubrication Force on a Bouncing Droplet.*

In our laboratory experiments, a shallow bath of silicon oil of a particular viscosity was placed on an electromagnetic shaker where it was driven by a constant frequency just below the threshold of Faraday instability. A small droplet was then manually created on the surface of the vibrating bath and the bouncing behavior of the droplet was observed and recorded with the aid of a high-speed camera. Droplets of sufficient size do not coalesce with the bath due to a thin air film that forms between them. Coalescence is avoided when the time for the bath to accelerate the droplet back into ballistic motion is shorter than the time required for the thin air film to deplete. Computer software was utilized to process the images and plot the dynamics of the droplet. The experimental data revealed that the acceleration of the droplets measured below -1 g at the moment when a droplet was being launched back into flight by the oscillating bath. In this presentation, we investigate whether lubrication theory accounts for these measurements. We use Matlab to plot the effects of different lubrication forces acting on simulated droplets of various radii. Finally, we model a bouncing droplet on a vibrating bath of the same viscosity with a lubrication force to reproduce our experimental data. (Received September 16, 2014)

1106-VG-2294 **Raquel A Barata*** (raquel.a.barata@gmail.com), **David R Thompson** and **Lance Christensen**. *Application of Gaussian Process and Maximum Entropy Sampling in Methane Plume Prediction.* Preliminary report.

We implement a Gaussian Process model in the prediction and visualization of a methane field. Starting with an initial training data set, we fit the Gaussian Process to the data by adjusting the hyperparameters of the covariance function using maximum likelihood estimation. Further refinements include the consideration of wind direction in the covariance function and implementation of the log-Gaussian Process to more accurately model extreme fluctuations in methane measurements. We couple this modeling approach with a sampling technique known as Maximum-Entropy Sampling. This method selects measurements that provide the most information about the Gaussian Process. Ultimately, the research will be applied in autonomous exploration where the user cannot specify their measurement objectives but the exploratory robot can perform adaptive sampling that accounts for previous measurement distributions or prior expectations. (Received September 16, 2014)

1106-VG-2385 **Atilla Sit*** (atilla.sit@eku.edu) and **Daisuke Kihara**. *Local Image Comparison Using Krawtchouk Moment Invariants.*

A new set of local moment invariants based on Krawtchouk polynomials is proposed for comparison of local patches in 2D images. Being computed from discrete functions, these moments do not carry the error due to discretization. Unlike many orthogonal moments which usually capture global features, Krawtchouk moments can be used to compute local descriptors from a region-of-interest in an image. This can be achieved by changing two parameters, and hence shifting the center of interest region horizontally and/or vertically. This property enables comparison of two arbitrary local regions. Krawtchouk moments are shown to be written as a linear combination of geometric moments, so easily converted to rotation, size, and position independent invariants. Formulations of these invariants will be presented, and their discriminative performance on local comparison of test images will be evaluated. (Received September 16, 2014)

1106-VG-2437 **Claudiu Mihai*** (cmihai@daemen.edu), 4380 Main St, Amherst, NY 14226, and **Christine Rakowski**. *A Piece of Paper and a Pair of Scissors.*

In this paper we will discuss the problem of splitting a given geometrical figure in two regions of equal area by drawing a line through a given point in the interior of the figure. For some geometric figures we will further discuss the possibility of splitting the figure in regions with areas p% and $(100-p)$%. (Received September 16, 2014)

1106-VG-2538 **Hashim AM Saber*** (hashim.saber@ung.edu), 3820 Mundy Mill Rd, Oakwood, GA 30566. *Surface Modeling of the left Ventricle of the heart.* Preliminary report.

The surgical treatment of mitral valve disease has dramatically improved with the recent development of repair techniques that avoid valve replacement with artificial valve. A better understanding of the dynamics of the normal and diseased mitral valve is necessary in order to design and test new repair maneuvers that would increase the scope of this surgery. In this talk I will explain how to produce wireframe images (model) of the left ventricle and mitral valve using Sonomicrometry distance data. The same data is used to construct the pressure-volume loops as the most reliable load independent index of left ventricular contractility. I will also discuss a proposed three-dimensional surface model that is based on three-dimensional (3D) Sonomicrometry data. Keywords: wire frame model, left ventricle, pressure –volume loop, surface modeling, Sonomicrometry data. (Received September 16, 2014)

1106-VG-2617 **Katherine M. Kinnaird*** (kkinnair@macalester.edu), Macalester College, MSCS Department, 1600 Grand Avenue, St. Paul, MN 55105. *Aligned Hierarchies for Sequential Data.*

We present *aligned hierarchies*, a novel solution to the dimension reduction problem, representing high-dimensional and noisy sequential data as a low-dimensional object that encodes relevant information. In this work, we motivate our presentation and discussion of aligned hierarchies through the lens of Music Information Retrieval (MIR), constructing aligned hierarchies by finding, encoding, and synthesizing all repeated structure present in a song. Given a particular MIR task, such as locating the chorus of a given musical song or finding all copies of a particular recording of a song, we compare songs based on their aligned hierarchies. Considering the fingerprint task and the cover song task, we present comparisons for two music data sets, one based on digitized scores and the other one performances of scores. Results from these comparisons on clean data had very high precision-recall values and provide a proof of concept for the aligned hierarchies. Results on noisy data were not as successful, but demonstrate the effect of different pre-processing techniques on the comparisons. (Received September 16, 2014)

1106-VG-2700 **Justin Droba*** (justin.c.droba@nasa.gov), Lyndon B. Johnson Space Center, 2101 NASA Pkwy, Houston, TX 77058. *Bringing the Orion Space Vehicle Home Safe: the Mathematics of Thermal Protection Systems.*

Toward the end of *Star Trek Into Darkness*, as the *Enterprise* begins a free fall toward Earth's surface, the crew frantically attempts to restore power to the shields to prevent the ship from being incinerated upon re-entry. In order to avoid a real-life version of this scene all too common in science fiction films, spacecraft employ thermal protection systems (TPS). Unlike the energy-based deflectors of the cinema, real TPS are made from advanced materials and are based on ablation, the process by which a solid loses mass by sublimation or vaporization. Due to the exorbitant cost of testing, NASA makes extensive use of simulation and reconstruction of flight data to develop TPS that will keep astronauts and their transport safe. This talk will discuss the mathematical models used in the design of TPS for modern spacecraft such as Orion, scheduled for manned operation in 2020. We will then discuss the computational challenges present in resolving these models and give a high-level discussion of some of the techniques used to surmount the difficulties encountered. (Received September 16, 2014)

1106-VG-2705 **Larry Wayne Lewis*** (llewis61@ivytech.edu) and **Rebecca Patterson** (becky.patterson@louisville.edu), KY. *Using Predictive Mathematical Modeling to Determine What Impacts Student Retention in the First, Second, and Third Years.*

Predictive mathematical modeling of student data can be an effective tool for addressing issues of enrollment management, institutional fit, and persistence to graduation. A predictive model was developed using the 2006 and 2007 Graduation Rate Survey (GRS) cohorts from a metropolitan research university and used to score the 2008, 2009, and 2010 cohorts. As a follow-up to two previous analyses focusing on student retention in the first year and second year, data from the National Student Clearinghouse were used to investigate issues of institutional fit and affordability for students persisting to the third year. A comparison of variables that impact retention in the first, second, and third years was developed. The changing profile of students as they progress toward graduation provides insight into new approaches to student programming designed to increase persistence to graduation. (Received September 16, 2014)

1106-VG-2828 **Roshan Thapaliya*** (roshanthapalia@gmail.com), 601 Fairmont Street NW, Washington, DC 20059, and **Brian Ricks**. *Using Crowd Simulation to suggest Efficient Evacuation in Emergency Situation.* Preliminary report.

Effective preparation for evacuation can save lives in the panic following an attack on a stadium. However, it is difficult for stadium security to know beforehand where to invest its resources. Using the deadly evacuation at the Bradford City Stadium as a guide for how people respond in panic situations, we created a model of stadium evacuation. Using this model, we simulated patron movements in a hypothetical stadium following an attack that also created a spreading fire. We studied the effect of such a stadium's preparation by varying preparation factors including speed of evacuation, loiter speed at barriers, fire growth rate, and the position of barriers. We then analyzed how these factors affected the survival rates of patrons. Our results suggest that preparing patrons to choose appropriate exits and creating an environment where they can move quickly most dramatically increased survival rates. These results are consistent with the data we obtained about the Bradford City event. (Received September 16, 2014)

1106-VG-2848 **Bryan Alexander Dawkins*** (bdawkins@uco.edu) and **Sean Michael Laverty**. *Analysis of the Innate and Adaptive Immune response in Antitumor Laser Immunotherapy.*

We will present a mathematical model describing the overall dynamics of the immune response in antitumor laser immunotherapy. Our analysis will include several laser immunotherapy treatment methods. The adaptive immune cells involved in treatment are Dendritic cells, Cytotoxic and Helper T cells, and B cells. Also, directly associated with adaptive immunity are antibodies and tumor antigen, which play a central role in the success of the treatment. We will discuss how the role of antibodies is related to regulatory T cells and innate immune system cells such as macrophages, natural killer cells, and neutrophils. We will describe how the possible outcomes of each treatment method is predicted by key parameters of our model. (Received September 16, 2014)

1106-VG-2854 **Jacob F Norton*** (jfnorton@ncsu.edu) and **Georgiy Bobashev**. *An Agent-based Model of Drug Switching Incorporating Ethnographic Data.*

Drug offenses are the single most common cause of arrest in the United States. Of the 12.2 million estimated arrests in 2012 in the US, 1.55 million were for drug abuse violations. Though many studies investigate risk factors, treatment outcomes, differences across gender and ethnicity, and individual user trajectories, most often, drug use dynamics of single drugs are explored without considering poly-drug use. However, there is mounting evidence that illicit drug markets adapt in ways that simple models do not predict. Missing is a description of a combination of individual choice and drug trajectories and illicit drug market adaptation without leadership. Agent-based modeling is a useful modeling framework when anticipating emergent behavior and faced with high complexity. Therefore, we developed an agent-based model to identify potential causal patterns and feedbacks that could predict drug use behavior quantitatively and qualitatively. Novelly, the agent-based model was populated using ethnographic data gathered from a drug-using population in Ohio. Finally, the agent-based model is used to assess the effect of idealized changes to the drug-using population. (Received September 16, 2014)

1106-VG-2865 **Jared Anthony Scolaro*** (jascolar@asu.edu), 1922 East Lodge Drive, Tempe, AZ 85283. *Social Insect Simulation.* Preliminary report.

The social dynamics of ants is particularly interesting during nest foundation. The harvester ant Pogonomyrmex Californicus displays two main strategies for nest founding. The preference for one strategy over the other is genetically linked, so one would think that a particular strategy would eventually prevail evolutionarily. However, these two strategies have been observed in coexistence for successive years in the same area. In order to understand how this could occur, I created a simulation of the lifecycle of queen ants with an agent-based modeling software. I attempted to capture the social dynamics of both strategies, as well as environmental factors. The results of the model show a close tie between environmental factors and behavioral differences. After numerous trials I began to identify which conditions generally favor which strategy. To strengthen the results I worked with several students and professors who had collected almost 1000 queens of this species, creating habitats for and recording the behavior of both types of queens. These results can be used to strengthen the model. This project allows a deeper understanding of the coexistence of the two strategies, and of cooperation more generally. (Received September 16, 2014)

1106-VG-2877 **Tim Antonelli*** (tdantone@ncsu.edu), **Michael A. Robert** and **Alun L. Lloyd**. *The effect of assuming a constant population size in models for the spread of Wolbachia.*

We demonstrate the impact of population dynamics on the predicted spread of *Wolbachia* using a simple continuous-time ordinary differential equation model for a well-mixed population. By incorporating density-dependent per capita growth rates, we demonstrate several scenarios in which our model produces qualitatively different predictions from frequency-only models, which assume that the population size is constant. Moreover, the “frequency threshold” required for *Wolbachia* to invade may not be constant, as is typically assumed, but rather depend on population size. This has important implications for optimizing release strategies that aim to drive *Wolbachia* into wild populations, as well as gene drive systems that exhibit frequency thresholds, such as underdominance. (Received September 16, 2014)

General Session on Outreach

1106-VH-951 **Alison Ahlgren Reddy*** (ared@illinois.edu), 1409 W. Green Street, Urbana, IL 61801. *University of Illinois and Urbana High School outreach collaboration to enhance student success in high school mathematics and improve the transition to college-level mathematics.* Preliminary report.

The University of Illinois and the Urbana School District have initiated an innovative collaboration whose fundamental goal is to enhance student success in high school mathematics, with a view towards helping them make the transition to college-level mathematics. Our project opens a new avenue for the university’s land-grant mission. It is a true collaboration, it is scalable, and has the potential to expand to involve community colleges and high schools throughout the state. Beginning Fall 2014, Illinois and USD are incorporating ALEKS, an online math assessment and instructional system, into Urbana High School Algebra I classrooms for a two-year pilot period. It will enable UHS teachers to better understand student mathematics capabilities and deficiencies.

We will also cooperate to evaluate the program. The College of Education and the I-STEM office have agreed to work with us on assessment of outcomes. During the second year of the pilot program, we will explore opportunities to expand the pilot program (adding other classes in USD and expanding to additional districts across the state). We envision expanding this collaboration to schools throughout Illinois. In order to do this, we anticipate developing connections with schools at all levels in other districts. (Received September 09, 2014)

1106-VH-1153 **Frank Sottile*** (sottile@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77843. *Texas A&M Math Circle.* Preliminary report.

The Texas A&M Math Circle is in its fourth year of operation, during which we have gone from a fortnightly after-school club of 10 students to a weekly activity of 50-60 in three classes.

While we have yet to converge on a stable organizational strategy, we have had some progress towards sustainability that I will report on. This includes diverse funding sources, an organizing committee of five, and recruiting volunteers and activity leaders from our department, University, and other Texas Math Circles. While every math circle is different, we face similar challenges, and sharing of notes may help other organizers. (Received September 11, 2014)

1106-VH-2121 **Polina D Sabinin*** (polina.sabinin@bridgew.edu), DEPT OF MATHEMATICS, Bridgewater State University, Bridgewater, MA 02325. *Games Teachers Play: Games as the vehicle for bringing deep mathematical thinking into PreK – 12 classrooms.*

Games Teachers Play (GTP) is an outreach program in mathematics and mathematics education. While playing games and solving puzzles, people of all ages can develop and exhibit more complex levels of reasoning than in any other situations. GTP provides current and future teachers of mathematics an opportunity to share and learn about the world of engaging mathematical games and how to incorporate them into their classroom in a way that is aligned with state standards. The presenter will provide examples of the types and structure of workshops that were offered, resources of appropriate games, as well as share frameworks, successes, and lessons learned. (Received September 15, 2014)

1106-VH-2154 **Sarah L. Mabrouk*** (smabrouk@framingham.edu), Framingham State University, 100 State Street, PO Box 9101, Framingham, MA 01701-9101. *The Regional Dinner Meeting: An Opportunity for Outreach, Interaction, and Learning.*

Since 2003, I have organized a regional dinner meeting in the Northeastern Section. This dinner meeting, which I named in memory of my colleague Kenneth J. Preskenis, has become an annual event providing opportunities for what Ken might call sharing good food with good friends, making new friends, and learning a bit of mathematics. The diverse presentations during the past twelve years have given students an opportunity to learn about, among other things, chaos and fractals, knot theory, using mathematics to model a zombie outbreak and to solve an art forgery case, and the connections of mathematics to art and music. In this presentation, I will share information about organizing the dinner meeting including support from within and outside the University, the wonderful mathematicians who have given presentations during the past twelve years, interaction between students and faculty during the dinner and reception, and attendance during presentations as well as how I use the presentations as a learning experience for my own students. (Received September 15, 2014)

1106-VH-2214 **Philip B Yasskin*** (yasskin@math.tamu.edu), Department of Mathematics, Texas A&M University, 3368 TAMU, College Station, TX 77843-3368. *Texas A&M Summer Educational Enrichment in Math (SEE-Math): Doing not Lecturing.*

Texas A&M's SEE-Math program is a 4 hours per day, 2 week, non-residential program for gifted and honors level students. It has been running since 2002. Although some of the activities develop computational and programming skills, most of the activities allow the students to experiment with manipulatives, develop conjectures and prove or disprove them. As time permits, I will discuss how we approach Map Coloring, Platonic Solids, Euler Numbers, Pick's Theorem and the Birthday Problem to emphasize Doing and not Lecturing. One of the activities which is unique to SEE-Math is Computer Animations using Maple programming. I will show several of the student produced animations. (Received September 16, 2014)

General Session on Probability or Statistics

1106-VI-129 **Hailin Sang** and **Lin Ge*** (lge@meridian.msstate.edu), 1000 Highway 19 North, M, MS 39307. *On the range of self-normalized Cramer type moderate deviations.*

We study the self-normalized Cramer type moderate deviations for centered independent random variables with finite third or higher moments and obtain the exact self-normalized tail probabilities for all $x = o(n^{1/2})$. This is an extension of the results in Jing, Shao and Wang (2003) where at most finite third moment is assumed. In particular, if the centered independent random variables have zero third moment, the Cramer type moderate deviations hold uniformly for x in a range which is related to the moments with order between 3 and 4. Further it is proved that the range $[0, o(n^{1/4})]$ is optimal under some regular moment conditions. We also show the necessity of the zero third moment condition in Cramer type moderate deviations for x outside the range of $[0, o(n^{1/6})]$. (Received July 28, 2014)

1106-VI-154 **Indika P Wickramasinghe*** (indika.wickramasinghe@enmu.edu), 1500 S Ave K, Station 18, Eastern New Mexico University, Portales, NM 88130. *Unit roots probabilities of the parameter of first order moving average model.*

Estimating the parameter, θ of moving average model of order one has practical importance. In this study, we estimate unit roots probabilities of the first order moving average model using the techniques of Maximum Likelihood Estimator (MLE) and Method of Moments (MOME). We consider random variables from the Gaussian distribution and the unit roots probabilities are compared under the two approaches of MLE and MOME. Results of the study conducted by Cryer and Ledolter (1981) are also compared with the results of this work. This study consider the instances of θ=0.2, 0.4, 0.6, and 0.8 and the sample sizes N=5, 10, 15, 20, 25, and 30. (Received July 31, 2014)

1106-VI-208 **Ibrahim Abdelrazeq*** (iabdelrazeq@gmail.com) and **Gail Ivanoff**, Ottawa, and **Rafal Kulik**. *Goodness of Fit Test: Recovered noise for CAR(1) Processes.*

When an Ornstein-Uhlenbeck (or CAR(1)) process is observed at discrete times 0, h, $2h$,$\cdots$ $[T/h]h$, the unobserved driving process (noise) can be approximated from the observed process. Abdelrazeq, Ivanoff and Kulik (2014) have used the approximated increments of the driving process to test the assumption that the process is Lévy-driven. If it can be concluded that the driving process is Lévy, the empirical process of the approximated increments can then be used to carry out more precise tests of goodness-of-fit. For example, one can test whether the driving process can be modeled as a Brownian motion or a gamma process. (Received September 01, 2014)

1106-VI-211 **Matthew L Wright*** (mlwright@ima.umn.edu). *Intrinsic Volumes of Random Cubical Complexes.*

How can we understand the size of noise in digital images? One way to answer this question involves studying intrinsic volumes of random sets. The intrinsic volumes generalize both Euler characteristic and Lebesgue volume, quantifying the size of a set in various ways. A random cubical complex is a union of (possibly high-dimensional) unit cubes, with vertices on an integer lattice, selected according to some probability model. I will describe a simple model of random cubical complex and provide exact polynomial formulae, dependent on a probability, for the expected value and variance of the intrinsic volumes of the complex. I will also give a central limit theorem and an interleaving theorem about the roots of the expected intrinsic volumes – that is, the values of the probability parameter at which an expected value is zero. Lastly, I will discuss applications such as image recognition. (Received August 11, 2014)

1106-VI-291 **Blane J Hollingsworth***, blanehollingsworth@gmail.com. *Small data sets with outliers and alternate measures of central tendency.*

For small data sets with potential outliers, finding the appropriate measure of central tendency is a challenge; with the mean, the outlier contributes too heavily, while the median fails to utilize much of the information. So, we consider alternatives such as m-tile means (the average of the quintiles, e.g.) and an iterated m-tile mean measure, using examples to compare/contrast their usefulness. (Received August 19, 2014)

1106-VI-477 **Santanu Chakraborty*** (schakraborty@utpa.edu), Department of Mathematics, University of Texas - Pan American, 1201 West University Drive, Edinburg, TX 78539. *Zero Inflated Negative Multinomial Distributions.*

Negative Multinomial distributions do exist in the literature for about half a century now. This particular multivariate distribution is considered if there is a possibility of more than one type of failures before achieving the required number of successes in an experiment. In such a case, Negative Multinomial distribution is the distribution of the failure vector where each vector component is a particular type of failure. Now it may so happen in an experiment that many of these failure types occur very rarely before getting the desired number of successes. So, for the corresponding data set in the experiment, there may be several zeros for some or even all of the components in the failure vector. For modeling such multivariate data, it makes sense to talk about zero inflated version of the Negative Multinomial distribution. In this article, we formally introduce Zero Inflated Negative Multinomial (ZINM) distribution. (Received August 29, 2014)

1106-VI-558 **Jasdeep Kaur Pannu*** (jkp0008@auburn.edu), 221 Parker Hall, Department of Mathematics & Statistics, Auburn University, Auburn, AL 36830, and **Nedret Billor** (billone@auburn.edu), 364-C Parker Hall, Department of Mathematics & Statistics, Auburn University, Auburn, AL 36830. *Robust Variable Selection in Functional Linear Models.*

We consider the problem of selecting functional variables using the L1 regularization in a functional linear regression model with a scalar response and functional predictors in the presence of outliers. Since the LASSO is a special case of the penalized least squares regression with L1 penalty function it suffers from the heavy tailed errors and/or outliers in data. Recently, the LAD regression and the LASSO methods have been combined (the LAD-LASSO regression method) to carry out robust parameter estimation and variable selection simultaneously for a multiple linear regression model. However variable selection of the functional predictor based on LASSO fails since multiple parameters exist for a functional predictor. Therefore group LASSO is used for selecting grouped variables rather than individual variables. In this study we extend the LAD-group LASSO to a functional linear regression model with a scalar response and functional predictors. We illustrate the LAD-groupLASSO on both simulated and real data. (Received September 02, 2014)

1106-VI-575 **Huybrechts F. Bindele*** (hbindele@southalabama.edu), 411 University Blvd. N., ILB 316, Dept. of Mathematics & Statistics, Mobile, AL 36688-0002, and **Yichuan Zhao** (yichuan@gsu.edu), 726, 7th Floor, College of Education Building, Dept. of Mathematics & Statistics, Atlanta, GA 30303-3083. *Signed rank regression inference via empirical likelihood.*

For the general stochastic regression analysis of complete data, Bindele and Abebe (2012) proposed the signed rank estimator. However, there exists an over-coverage problem for the confidence intervals of the regression parameters when the sample size is small. In this paper, we investigate an empirical likelihood approach to construct confidence intervals for the regression parameters based on the signed-rank estimating equation. The limiting distribution of log-empirical likelihood ratio is χ^2 distribution. We carry out extensive simulation studies to compare the proposed method with the normal approximation based method. The simulation results show that the proposed methods outperform the existing method in terms of the coverage probability and average length of confidence intervals. We illustrate the empirical likelihood method using a real data example. (Received September 02, 2014)

1106-VI-581 **Melody Denhere***, Dept. of Mathematics, 1301 College Avenue, Fredericksburg, VA 22401, and **Frazier Bindele**. *Rank Estimation for the Functional Linear Model.*

In this work we discuss the estimation of the parameter function for a functional linear regression model under heavy tailed errors' distributions and in the presence of outliers. Standard approaches of reducing the high dimensionality, which is inherent in functional data, are considered. After reducing the functional model to a standard multiple linear regression model, a weighted rank-based procedure is carried out to estimate the regression parameters. A Monte Carlo simulation and a real world example are used to show the performance of the proposed estimator and a comparison made with the LS and LAD estimators. (Received September 02, 2014)

1106-VI-660 **Quy Xuan Cao*** (quy.cao@coyotes.usd.edu), Department of Mathematical Sciences, University of South Dakota, Vermillion, SD 57069, and **Y. L. Lio**, **Nan Jiang** and **T. -R. Tsai**. *A Dynamic System Based on Weibull Distribution.* Preliminary report.

In this research, the Weibull distribution is proposed for the baseline lifetimes of components in a composite system. In this composite system, the failure of a component induces a higher load on the surviving components and increases component hazard rate via a power-trend process. The likelihood function based on the component lifetimes of the composite system is studied, and the likelihood equations are established. A testing procedure is proposed for examining the relationship between the hazard rate function and the number of failed components. Intensive simulations have been conducted to evaluate the performance of the proposed procedures. Key words: Generalized likelihood ratio test; Log-likelihood function; Sequential order statistics. (Received September 04, 2014)

1106-VI-667 **Rasitha Rangani Jayasekare***, rasitha.jayasekare@centre.edu, and **Ryan Gill** and **Kiseop Lee**. *Modeling Stock Price Changes using a Finite Mixture.*

Mixture models have attracted many different fields in recent decades. This presentation uses an application of mixture models to model discrete changes in the stock market price with respect to the 'tick size'. We study how the changes in the stock price are associated with the order size of the transaction. The parameters are estimated using the Expectation - Maximization (EM) algorithm with a constant mixing probability as well as mixing probabilities which depend on order size. Consistency and asymptotic normality of a sequence of estimators are proved, and asymptotic confidence intervals for functions of the parameters are derived. The model is tested using stock transactions data from Federal Express. (Received September 04, 2014)

1106-VI-668 **Trenton Nash Brown*** (trenton.brown@coyotes.usd.edu), 103 N. Harvard St., Unit #1, Vermillion, SD 57069, and **Yuhlong Lio** and **Nan Jiang**. *Maximum Likelihood Estimation for the Generalized Exponential Distribution Parameter under Progressive Type-II Centering.*

In industrial life time testing and medical survival analysis, progressively censored schemes have received special attention in the last two decades. The Generalized Exponential distribution was introduced by Mudholkar and Srivastava (1993). Since then, the Generalized Exponential distribution has been shown to be a popular lifetime distribution model. In this study, the maximum likelihood estimates for the parameters of the Generalized Exponential Distribution based on the progressively type-II censored sample are investigated in terms of mean squared error and bias through an intensive simulation. Finally, a real data is used for illustration. (Received September 04, 2014)

1106-VI-898 **Salam Md. Mahbubush Khan*** (salam.khan@aamu.edu), Department of Mathematics, Alabama A&M University, Huntsville, AL 35810. *Approximations of Generalized Negative Binomial Distribution.*

The generalized negative binomial distribution is a three parameter distribution. This distribution is becoming increasingly useful in many branches of science specially related to customer service and queueing processes. Generalized distributions are becoming increasingly evident and useful in many branches of science but the functional forms of these generalized distributions are often complicated. Therefore, there arises a need to have some simplified or approximated form of this generalized distribution and also to know their relations with other distributions. Here we approximate the generalized negative binomial distribution by using different techniques and suggested the best approximation. The results are intended to fill a conspicuous gap in the mathematical and statistical literature concerning the empirical quality of the approximations, and they are useful for designing efficient and accurate computing algorithms for such probabilities. (Received September 08, 2014)

1106-VI-936 **Lina Wu*** (lwu@bmcc.cuny.edu), 529 West 42nd Street Apt. 5K, New York, NY 10036, **Wenyi Lu** (wlu1@gc.cuny.edu), 365 Fifth Av., New York, NY 10016, and **Margaret Dean** (mdean@bmcc.cuny.edu), 199 Chambers Street, New York, NY 10007. *Incorporating Quantitative Reasoning Skills in College Statistics Education.* Preliminary report.

Quantitative Reasoning (QR) skill is a person's ability to understand data, interpret data, analyze data, and make decision from data in the data-driven society. In college statistics class, the challenge is how to teach students statistical thinking and data-analyzing by developing their quantitative reasoning skill. The presenter will introduce the pedagogy of designing QR projects to facilitate students' learning and designing assessment tests to evaluate students' performance that were used in the Spring 2014 pilot statistics courses. The same QR projects and the same assessment tests were conducted at Borough of Manhattan Community College and Brooklyn College. Results of students' performance from these two colleges will be compared at the end of this presentation. (Received September 08, 2014)

1106-VI-1047 **Paolo Rocchi*** (procchi@luiss.it), via Salvini 2, 00197 Roma, Italy. *The Interpretation of Probability is not a Philosophical Argument.* Preliminary report.

It is worth underlying that in exact science the interpretation of a variable is established on the basis of a mathematical equation and not using philosophical statements. In particular the argument of the equation determines the exact physical significance of the result. Take, for instance, the time derivative: $y = dx/dt$. The significance that y has in the world depends on x; e.g. if x is the space s, then we obtain the linear velocity $v = ds/dt$; if x is the angular displacement α, then we obtain the angular velocity $\omega = d\alpha/dt$. It is evident how philosophical starting points are inappropriate to establish the meaning of probability and I propose two theorems in [1]. The former is the theorem of large numbers, which holds that $P(A_n)$ can be controlled in the physical reality, and thus $P(A_n)$ is a real quantity. The second theorem – called theorem of a single number – demonstrates that the probability of a single experiment $P(A_1)$ cannot be experienced in the world, thus $P(A_1)$ does not exist in the world as a real quantity. However, people is very concerned with $P(A_1)$ and we can assign a personal value to $P(A_1)$. [1] P. Rocchi – Janus-Faced Probability – Springer (2014). (Received September 10, 2014)

1106-VI-1086 **Justin R. Sims*** (justin_sims@baylor.edu), **Jane L. Harvill** and **Clifford W. Hansen**. *Optimal Sensor Design for Photovoltaic Power Plants.*

Assessment of a utility scale photovoltaic (PV) power plant's potential performance is a critical aspect in the initial plant design and construction, and accurate monitoring of plant efficiency is crucial to profitable plant operation. Both assessment and monitoring rely on measurement of irradiance at the plant's location. These measurements are typically made using pyranometers which provide temporally dense, but spatially sparse data. Because plant output is directly related to total irradiance over the plant's footprint, a natural question is, "What is the optimal number and layout of sensors for predicting solar irradiance?" We propose a sensor design algorithm in an attempt to answer this question. The algorithm makes use of nonlinear time series models to determine if an optimal sensor design exists. To illustrate utility, we apply the algorithm to irradiance data collected from a 1.2 MW PV plant located in Lanai, Hawaii. (Received September 10, 2014)

1106-VI-1133 **Sami Cheong*** (cheongs@uwm.edu). *Parameter Estimation of Correlated Spatial Data using EM Algorithm.* Preliminary report.

In this presentation, we propose an expectation-maximization (EM) approach to estimate the parameters of spatially correlated data modeled as realizations of an Ornstein-Uhlenbeck (O-U) process. In particular, we will

review : 1) the properties of the O-U process 2) the properties of an EM algorithm and 3) illustrate and discuss the parameter estimation procedure under different cases of simulated data. (Received September 10, 2014)

1106-VI-1188 **Ram C Kafle*** (rckafle@shsu.edu), Department of Mathematics and Statistics, Sam Houston State University, Huntsville, TX 77341, **Netra Khanal** (nkhanal@ut.edu), Department of Mathematics, Tampa, FL 33606, and **Chris P. Tsokos** (ctsokos@usf.edu), Department of Mathematics and Statistics, Tampa, FL 33620. *Modeling Carbon Dioxide Emission Data using Functional Data Analysis Approach.* Preliminary report.

Carbon dioxide (CO2) is one of the major contributors in Global Warming. In this study, we aim to develop a system of differential equations using time series data of significant contributable variables of carbon dioxide in the atmosphere in the continental United States. We define the differential operator as data smoother and use the penalized least square fitting criteria to smooth the data. Finally, we optimize the profile error sum of squares to estimate the necessary differential operator. The proposed models will give us an estimate of the rate of change of carbon dioxide in the atmosphere. The data set is obtained from the Carbon Dioxide Information Analysis Center (CDIAC), the primary climate-change data and information analysis center of the United States Department of Energy. (Received September 11, 2014)

1106-VI-1242 **Mehdi Razzaghi*** (mrazzagh@bloomu.edu), Department of Mathematics, Bloomsburg University, Bloomsburg, PA 17815. *Approximating the Distribution of Combined Dependent P-values from Multiple Experiments.*

Observed significance levels or what is commonly known as p-values are routinely used to summarize the results of hypotheses tests. In many experiments, however, it is necessary to summarize results of multiple tests and combine several p-values to arrive at a single observed significance level for the entire experiment. When these p-values are assumed independent, then the classical approach to combining p-values is rather straight forward. However, when the p-values from multiple tests are not independent, the problem is more complex and no closed form distribution can be derived. For such cases, one approach is to use a shifted chi-square distribution to approximate the distribution. Method of moments has traditionally been utilized to estimate the shift parameter as well as the number of degrees of freedom. Here, we propose a method that does not only rely on matching the first two moments. Rather, our method is based on minimizing the distance between the moment generating functions for a chosen set of moments. An approximation for the moment generating function of the distribution of the combined p-values is derived and is used to determine the parameter estimates. The properties of the estimates are discussed and an example is used to illustrate the methodology. (Received September 15, 2014)

1106-VI-1411 **Zengxiang Tong*** (ztong@otterbein.edu), Department of Mathematical Sciences, Otterbein University, 1 S Grove Street, Westerville, OH 43081. *A Functional Equation and Normal Distribution.* Preliminary report.

The binomial distribution, Poisson distribution, and normal distribution are three most important distributions in probability theory. Most textbooks introduce the first two distributions in a very educational way: real life examples, mathematics models, mathematical reasoning, and the rigorous derivation of their probability mass functions. However, no textbook I have ever seen introduces the normal distribution in this way. All books simply gives the weird probability density function, which often scares students away. This paper starts from the target shooting, analyzes it, mathematically models it, and uses functional equation to derive the probability density function of normal distribution. The author strongly recommends this example to all probability professors and textbook writers in hope of enhancing the quality of probability education. (Received September 12, 2014)

1106-VI-1478 **Marina L Massaro*** (marina.massaro@gmail.com), Geneseo, NY 14454, and **Kelly R Moran**. *An Analysis of the Coherence Between Experiential and Behavioral Emotional Response During Ambiguous Emotional Stimuli.* Preliminary report.

In 1971, Paul Ekman published that the six basic emotions (anger, happiness, surprise, disgust, sadness, and fear) have distinct, universal facial expressions. Past studies confirm that high levels of coherence exist between emotional experience and facial expression when subjects are shown poignant film clips. But what happens to the tie between emotional experience and facial response when the eliciting event isn't purely of one sentiment? In this study, data collected from video recordings of individuals watching ambivalent film clips are used to examine the relationship between emotional experience and facial response when mixed emotion is elicited. Cross-correlations between data sources measuring positive and negative emotional response indicate low to moderate amounts of coherence between response systems. Contributors to coherence are being investigated, including the degree to which emotion is "mixed" at a given time, individual personality characteristics, and attitude toward various emotions. Furthering the understanding of response coherence and mixed feelings will shed light on various psychiatric disorders, where emotional dysfunction skews the normal emotional experience and response. (Received September 13, 2014)

1106-VI-1733 **Eddy A Kwessi*** (ekwessi@trinity.edu), One Trinity Place, San Antonio, TX 78212, and **Brice M Nguelifack** (bmn0003@auburn.edu), Auburn, AL 36849. *Signed-Rank Estimation of Partial Linear Models with B-splines.*

For a partially linear regression model, we propose a Signed-Rank estimation method. The proposed estimator for the linear unknown parameter vector is shown to have root-n consistency while monotone B-splines are used to estimate the unknown nonparametric function. Finite samples simulations are carried out to evaluate the performance of the proposed method and practical applications including the study of Air Pollution data and the study Survival Time after Liver Transplant data are given. (Received September 15, 2014)

1106-VI-1819 **Mark A. Krines*** (krinesm@uwstout.edu). *An Exploration of the Impact of Iteration on Positional Election Procedures.*

Election procedures often produce collective outcomes which can change if one or more of the candidates is removed from consideration. In such situations, the voting public might perceive that the collective outcome is "unfair". We can utilize a statistical model to calculate numerical probabilities for the likelihood that iteration will influence the outcome of a positional procedure election. This talk will discuss these probabilities and how they impact the practical use of iterated positional procedures such as Instant-Runoff Voting and Baldwin's Method. (Received September 15, 2014)

1106-VI-1898 **Mahshid Atapour*** (atapour@math.usaskca), Saskatoon, SK S7N5A7, Canada, and **Neal Madras**. *Ratio limit theorem and shape results for pattern-avoiding permutations.*

A permutation p of 12...N is said to contain a pattern (relatively shorter permutation) q of length k if p contains a substring of length k that has the same relative order as q. Let SN(q) denote the set of permutations of length N which avoid the pattern q. In this talk, I will present a brief sketch of the proof of a ratio limit theorem for the number of q-avoiding permutations when q belongs to some specific classes. Considering a permutaion of length N as a set of N points in the xy-plane, I will also discuss some results about the typical shape of some q-avoiding permutations in the xy-plane. This is a joint work with Neal Madras. (Received September 15, 2014)

1106-VI-1950 **Mitra Lal Devkota*** (mdevkota@shawnee.edu), Department of Mathematical Sciences, 940 Second Street, Portsmouth, OH 45662, and **Gary D Hatfield** and **Saroj Thapa**. *Statistical Analysis of Land Cover of South Dakota.*

This paper focused on how land cover of South Dakota had changed over the years 2001-2006. Furthermore, this study explored the relationship of population density with respect to agricultural land cover in South Dakota. Several statistical methods such as correlation analysis, ordinary least squares, conditional autoregressive models, and simultaneous autoregressive models were used for the analysis of the data. The results showed that the agricultural land cover, developed land cover, and grass land covers increased while the forest land cover decreased from 2001 to 2006. The study assessed that agricultural land cover had a positive correlation with population density. The ordinary least squares model with agricultural land cover as a response variable and population density as independent variable showed that the relationship between the two variables was statistically significant. It was found that there was a poor spatial autocorrelation in the residuals for all OLS, SAR, and CAR models for both years. (Received September 15, 2014)

1106-VI-2004 **Michael Johnson**, **Sarjinder Singh** and **Stephen Sedory*** (kfsas00@tamuk.edu). *Efficient Use of the Negative Hypergeometric Distribution in Randomized Response Sampling.*

Many questions, whose answers are of interest to sociologists and government policy makers, are sensitive, and people being surveyed are often hesitant to respond, or are reluctant to respond truthfully. Randomized response techniques are methods to estimate, through face to face surveys, such things as the proportion of persons in a population who are members of a (sensitive) subgroup, while, at the same time protecting the individual's privacy. In this talk we look briefly at a few common methods, give an indication of how these methods work, and then look at a newly proposed estimator, based on the negative hypergeometric distribution, that turns out to be more efficient than several standard estimators. (Received September 15, 2014)

1106-VI-2186 **Pallavi Sawant*** (pallavirs@ksu.edu), Department of Statistics, Kansas State University, 101 Dickens Hall, Manhattan, KS 66506, and **Nedret Billor**. *Robust Principal Components For Multivariate Functional Data.*

In this study, robust multivariate functional principal component analysis (RMFPCA) method is proposed to achieve dimension reduction and to develop tools for detection of outliers in a functional dataset. We extended the method of M-type smoothing spline estimators for principal functions by Lee et al. (2013) to multivariate functional data. Simulation study and real world example are provided to illustrate the numerical performance of the proposed method. (Received September 16, 2014)

1106-VI-2192 **Khyam Paneru*** (paneruk@uww.edu), Department of Mathematics, University of Wisconsin-Whitwater, Whitewater, WI 53190. *Estimation of expected responses at "future" covariate values/vectors in zero-inflated generalized linear model under unequal probability sampling designs.*

An underlying population may contain a large proportion of zero values which causes the distribution spiked at zero, and such population is referred to as zero-inflated population. In statistical analysis of such populations, a common problem known as zero-inflation is caused by the presence of a large proportion of zero values. I will present some examples of zero-inflated population in important applications such as insurance, auditing, meteorology, and manufacturing. I will describe zero-inflated generalized linear model under unequal probability sampling designs via two-component mixture models where probability distribution of non-zero component is known. Since the exact likelihood function is not known due to complex probability sampling designs, pseudo-likelihood function is defined. I will introduce maximum pseudo-likelihood procedure to estimate the expected responses at "future" covariate values/vectors. The simulation results show that maximum pseudo-likelihood procedure gives significantly and systematically shorter confidence intervals. (Received September 16, 2014)

1106-VI-2306 **Bruce W. Atkinson*** (bwatkins@samford.edu), Samford University, Dept. of Math/CS, Birmingham, AL 35229. *Simple evolving sequences.* Preliminary report.

Fix N. Let $\{z_1, z_2, \dots\}$ be an i.i.d. sequence of random choices from the set $\{1, 2, \dots, 2N\}$. Let $(y_{n,1}, y_{n,2}, \dots, y_{n,2N}) = (z_{2N(n-1)+1}, z_{2N(n-1)+2}, \dots, z_{2Nn})$. We construct a process (X^n) as follows: $X^0 = (1, 2, \dots, 2N)$, and $X_i^{n+1} = X_{y_{n+1,i}}^n$; i.e. the sequence X^{n+1} is obtained by random sampling from X^n.

We can think of the process (X^n) as a sequence of "populations". (X^n) is a Markov chain having the constant sequences as absorbing states. (X^n) can also be used as a base structure for the construction of other Markov Chains. For example, if we initially label some of the elements of $\{1, 2, \dots, 2N\}$ as a certain type of allele, then the sequence which counts that allele in each population is a Markov Chain with state space $\{0, 1, 2, \dots, 2N\}$. This is the well-known Wright-Fisher model of pure genetic drift.

We will analyze other objects related to the the chain (X^n), such as the distribution of the absorption time. This research is part of a grant, "Who Pulls the Random Strings in Neural Evolution", at Samford University, which concerns evolving genomes that generate neural networks. In the general case, successive populations are determined using a genetic algorithm. (Received September 16, 2014)

1106-VI-2312 **Mikhail Neklyudov*** (mikhail.neklyudov@sydney.edu.au), School of Mathematics and Statistics F07, University of Sydney, Sydney, NSW 2006, Australia. *Dynamics of nanomagnetic particle systems.*

In the talk we will discuss the long time behaviour of the stochastic Landau-Lifshitz-Gilbert equation and its structure preserving discretisations. (Received September 16, 2014)

1106-VI-2369 **Paul H Bezandry*** (pbezandry@howard.edu), 2441 6th street, NW, Washington, DC 20059. *Almost periodic sequences and applications.* Preliminary report.

In this talk, we introduce a concept of almost periodicity for random sequences. We then apply this concept to study the existence and uniqueness of the almost periodic solution to some Volterra stochastic difference equation in a Banach space. (Received September 16, 2014)

1106-VI-2373 **Veroni Jayawardana*** (jayawavn@clarkson.edu), NY , and **Sumona Mondal** (smondal@clarkson.edu). .

The purpose of this study was to assess the presence of factors contributing to movement-related fear for subjects with Fibromyalgia (FM) based on the collected data by a national internet survey of community-based individuals. The study focused on variables Activities-Specific Balance Confidence scale (ABC), Primary Care Post-Traumatic Stress Disorder screen (PC-PTSD), Tampa Scale of Kinesiophobia (TSK), a Joint Hypermobility Syndrome screen (JHS), Vertigo Symptom Scale (VSS-SF), Obsessive-Compulsive Personality Disorder (OCPD), Pain, work status and physical activity dependent on "Revised Fibromyalgia Impact Questionnaire" (FIQR).

Results indicated function (FIQR) was highly correlated to Pain, ABC, VSS and TSK. A linear regression using both the methods Best Subset Regression (Russek et al.(2014)) and Bayesian analysis with appropriate priors (Jayawardana et al.(2014)) showed the contribution of significant factors in expected directions. Finally, Missing values were interpreted using Multiple Imputation, obtained a regression model with imputed values and compared with the previous models.
(Received September 16, 2014)

1106-VI-2383 **Katerina Tsakiri*** (k.tsakiri@brighton.ac.uk), University of Brighton, Watts Building, Lewes Road, Brighton, Brighton BN25PH, United Kingdom, and **Antonios Marsellos** and **Igor Zurbenko**. *A Time Series Model for the Prediction of Flooding in Water Rivers.*

A time series model is presented for the explanation and prediction of the daily water discharge time series derived by three locations nearby Mohawk River, New York and the county of Kent, United Kingdom during the period of 2005-2013. For the analysis, we use the daily water discharge time series, the daily data of ground water level, and climatic variables. A methodology is used to decompose the time series of all the variables into different components (long, seasonal and short term component). The Kolmogorov-Zurbenko (KZ) filter is used for the decomposition of the time series. The KZ filter which separates the long term variations from the short term variations in a time series provides a simple design and the smallest level of interferences between the scales of a time series. The application of the KZ filter in an example of Schoharie Creek (nearby Mohawk River) has improved the prediction of the water discharge up to 81%. This methodology can be applied for the prediction of flooding of the rivers in multiple sites. (Received September 16, 2014)

1106-VI-2413 **Devin P Kapper*** (kapperdp@clarkson.edu), **Sumona Mondal** and **Martin D Heintzelman**. *Analysis of Property Values in New York State: Transactions vs. Assessments.* Preliminary report.

Property values are known to be affected by a number of characteristics, including their geospatial location, size, and various property attributes. This study uses fixed effects hedonic analysis using census block groups to analyze the differences between assessed property values and the real market value of properties as determined by sale price. In this study, we consider property sales from 2004 to 2013 in fifty-five of New York State's counties–neglecting the seven counties in New York City and Long Island, which represent a different real estate market. Our findings provide evidence that assessed property values are biased when compared to transaction values, which includes overvaluing some characteristics and undervaluing others. (Received September 16, 2014)

1106-VI-2470 **Krishna Kaphle*** (krishna.kaphle@maine.edu). *Equality of covariance operators when data are in functional space.* Preliminary report.

While dealing with means of several population, we assume covariance operators to be equal. Eigenvalues, eigenvectors and eigenprojections of a covariance operator play an important role while testing equality of covariance operators. We will discuss on the problem of testing equality of covariance operators for based on samples of functional data.
(Received September 16, 2014)

1106-VI-2487 **Taysseer Sharaf***, tsharaf@mail.usf.edu, and **Chris Tsokos**. *Artificial Neural Network for Competing risks using Bayesian Learning.*

In the current study, we introduce a new method of utilizing artificial neural network (ANN) in modeling survival data of competing risks. We used Bayesian learning for a neural network to estimate the weights of ANN and to select the best ANN model. The proposed method is used to study the risks associated with patients diagnosed with melanoma (skin cancer). Patients' information diagnosed with melanoma in the united states from the year 2000 to 2010 were gathered from the Surveillance, Epidemiology, and End Results Program (SEER). We used Harrell's c-index to compare between various models of ANN. (Received September 16, 2014)

1106-VI-2512 **Bhikhari P. Tharu***, bhikhari@mail.usf.edu, **Ram C. Kafle**, rckafle@shsu.edu, and **Chris P. Tsokos**, ctsokos@usf.edu. *Modeling Lung Cancer Mortality Using Bayesian Analysis.*

Lung cancer is the leading cause of cancer death in the US where cancer remains the second most common cause of death. In this study, we aim to develop time trends of lung cancer mortality in the US for periods 1970-2010 for age groups 20-84 years through age-period-cohort (APC) model. Bayesian age drift model has been used to describe the trends. Second order random walk methods have been adapted to smooth the data. The proposed model will give an estimate of the rate of change of mortality due to lung cancer in the US. The data set is obtained from the Surveillance, Epidemiology, and End Results (SEER) Program of the National Cancer Institute (NCI). (Received September 16, 2014)

1106-VI-2533 **Ahmad Alzaghal*** (ahmad.alzaghal@oswego.edu), 124 Tallman St., Oswego, NY 13126, and **Indranil Ghosh** and **Ayman Alzaatreh**. *Weibull Lomax distribution: An alternative to Weibull-Pareto distribution.*

The Lomax distribution, conditionally known as Pareto (type II) distribution, is a heavy tail probability distribution used extensively in business, economics, and actuarial modeling. In this paper we consider a new absolutely continuous distribution, Weibull-Lomax distribution, following the technique of mixing two continuous distributions. It is observed that the Weibull-Lomax distribution can provide a better fit to the data as compared to Weibull-Pareto model because of greater efficiency in estimating model parameters of the former over the later. For illustrative purposes a real life data set is considered as an application of the Weibull-Lomax model. (Received September 16, 2014)

1106-VI-2557 **Ying-Ju Chen*** (yingc@bgsu.edu), **Wei Ning** (wning@edu.tw) and **Ajrun K. Gupta** (gupta@bgsu.edu). *Jackknife Empirical Likelihood Based Detection Procedure for Change-Point in Mean Residual Life Functions.*

Mean residual life function is an important function in survival analysis which describes the expected remaining lifetime given survival time up to a certain age. In this talk, I will introduce the nonparametric method based on Jackknife empirical likelihood through U-statistic to test the change point of mean residual life functions of independent random variables. The test statistic and its asymptotic distribution are investigated. Monte Carlo Simulations under different lifetime settings are carried out to show the power performance and the control of Type I error. The real data example is analyzed to illustrate the testing procedure. (Received September 16, 2014)

1106-VI-2589 **Budhinath Padhy*** (budhinath@yahoo.com), **Kenneth R Emo**, **Gemechis Djira** and **Amit V Deokar**. *Analyzing Factors Influencing Teaching as a Career Choice using Structural Equation Modeling.*

The purpose to the study is to analyze factors influencing students' perceptions of teaching as a career of choice using structural equation modeling with the goal of shaping a teacher education recruitment program. In this study, 458 students from a Midwestern university in United States responded to an online survey about career-related factors they *value*, their *expectation* that teaching would offer those factors, and any social influence factors that might encourage them to choose a teaching career. We have used Exploratory Factor Analysis to determine the underlying value-related, expectancy-related and social-influence-related factors. The effect of these exogenous latent factors on choosing a teaching career was examined. Results of our analysis showed that respondents' highly-valued career factors had no effect on their likelihood of teaching. Rather, respondents' expectation of teaching and a variety of social influence were the strongest predictors of increased likelihood of considering teaching as a career option. (Received September 16, 2014)

1106-VI-2736 **Benjamin David Knisley*** (bknisleystatistics@gmail.com), 8432 Magnolia Ave, PMB 140, Riverside, CA 92504, and **Grace Crosby**, **Hannah Te Stipek**, **Margaret Barth, PhD** and **Linn Carothers, PhD**. *Anthropometric and nutritional correlates of obesity in Native American adolescents.* Preliminary report.

The American obesity epidemic requires methods for identifying those at risk among minority populations, especially among Native American adolescents. Nutritional studies indicate the prevailing onset of Type 2 diabetes is related to American diets and educational policies. Our study focused on several nutritional and anthropometric measures which in combination are appropriate to assess obesity in Native American adolescent populations. Data was compared to standards drawn from Centers for Disease Control and Prevention (CDC), and the National Health and Nutrition Examination Surveys (NHANESIII). Our study population represents a cross-sectional, epidemiological population (N=183) of Native American students (ages 14-18) from diverse tribal backgrounds at an urban residential high school. Factors of time, gender, and diet proved significant correlates for increasing risk of obesity. Under the conditions of our study, the enormity of fat intake overwhelmingly suggests a need to shift diets and policies in our population. Assessment of health risk by anthropometric measures appears appropriate for predicting obesity and developing effective health interventions. (Received September 16, 2014)

1106-VI-2935 **Doo Young Kim*** (dooyoungkim@mail.usf.edu) and **Chris P. Tsokos**. *A Transitional Modeling of Carbon Dioxide in the Atmosphere by Climate Regions in the United States.*

Global Warming is a function of two main contributable entities in the atmosphere, carbon dioxide and atmospheric temperature. The objective of this study is to develop a statistical model using actual fossil fuel carbon dioxide emissions data from the United States to predict relative probability of rate of change in fossil fuels carbon dioxide emissions from nine US climate regions using transition modeling. The sensitivity of these transition probabilities to five sectors: commercial, industrial, residential, transportation, and electric power sector, is investigated for all nine US climate regions. The present study also proposes in developing carbon dioxide regions in the United States based on relative probabilities of rate of change in fossil fuel carbon dioxide emissions to assist in establishing different policies for each region to control the fossil fuel carbon dioxide emissions in the United States. (Received September 17, 2014)

General Session on Research in Algebra

1106-VJ-404 **Hy Ginsberg*** (hginsberg@worcester.edu). *Heilbronn Characters of Finite Groups.*

In 1973 Hans Heilbronn described a virtual character associated to representations of Galois extensions of number fields as a tool for the study of zeros of Dedekind ζ-functions and Artin's Conjecture on the holomorphy of L-series. His construction has since been generalized by Richard Foote and others into what are now called *Heilbronn characters* of arbitrary finite groups. In 2010 we showed that, apart from certain 2-dimensional linear groups, groups possessing so-called *unfaithful minimal* Heilbronn characters are quasisimple and have a cyclic Sylow p-subgroup P for some odd prime p such that $N_G(P)$ is the unique maximal subgroup of G containing $\Omega_1(P)$ (the unique subgroup of P of order p). We will describe recently completed research classifying precisely which finite groups these are. (Received August 27, 2014)

1106-VJ-420 **Amanda K. Sutherland*** (aksuther@ncsu.edu). *Generalizations of the Cartan and Iwasawa Decompositions for SL$(2,k)$.*

The Cartan and Iwasawa decompositions of real reductive Lie groups play a fundamental role in the representation theory of the groups and their corresponding symmetric spaces. These decompositions are defined by an involution with a compact fixed-point group, called a Cartan involution. For an arbitrary involution, one can consider similar decompositions. We offer a generalization of the Cartan and Iwasawa decompositions for $\mathrm{SL}(2,k)$ defined over an arbitrary field k and a general involution. (Received August 27, 2014)

1106-VJ-1000 **Michelle Knox*** (michelle.knox@mwsu.edu), **Warren McGovern** and **Ricardo Carrera**. *Properties of the Ring $A(X)$.* Preliminary report.

Let X be a Tychonoff space with a clopen π-base, and let $C(X)$ be the ring of continuous functions from X into $\mathbb{R}$. We will discuss some ring-theoretical properties of the ring $A(X) = \{f \in C(X) : f^{-1}(O)$ is an open set in X for every open set $O \subseteq \mathbb{R}\}$ and compare them to properties of $C(X)$. (Received September 09, 2014)

1106-VJ-1057 **Mark C Hunnell*** (mchunne2@ncsu.edu). *Generalized Complexification of the Orbits of Parabolic k-subgroups Acting on Symmetric k-Varieties.* Preliminary report.

Symmetric k-varieties are a generalization of real reductive symmetric spaces occurring in many areas of mathematics including number theory, geometry, and combinatorics. Parabolic k-subgroups act on these k-varieties and these orbits are fundamental to representation theory. To characterize these orbits one can first consider the orbit decomposition over an algebraically closed field and then determine how these orbits split in to k-orbits. One can reverse this process by extending k-orbits to orbits over the algebraic closure, a process we call generalized complexification. Generalized complexification does not always yield all of the orbits over the algebraic closure of the base field k. We give a condition to determine when this map is surjective. (Received September 10, 2014)

1106-VJ-1109 **Jessica L Williams*** (jessica-l-williams@uiowa.edu), 14 MacLean Hall, University of Iowa, Iowa City, IA 52242. *Radicals of Extensions.* Preliminary report.

This is a report on a Ph.D. thesis project with an emphasis on advanced undergraduate accessibility. Let A and B be Abelian groups and X be an extension of B by A. What is the Jacobson radical of X? Suppose A is an infinite direct sum of simple Abelian groups and B is the rational numbers. A subtle, surprising, homological proof shows that the corresponding extension has non-zero Jacobson radical if and only if the extension splits. We are also able find a direct, computational proof. This motivates consideration of a general case: R is a commutative ring, A is a suitably conditioned torsion R-module and B is an R-module with some divisibility properties. Examples and results are discussed, including problems that arise by translating this project into the language of presentations and infinite matrices. (Received September 11, 2014)

1106-VJ-1224 **Berit Nilsen Givens*** (bngivens@csupomona.edu), **Amber Rosin** and **Karen Linton**. *The homomorphic image of a variant of the bicyclic semigroup.*

The bicyclic semigroup $C = C(p, q)$, defined by two generators with the relation $pq = 1$, is an oft-studied semigroup. The simplicity of its definition and its highly structured form give it several nice properties. In particular, the only homomorphic images of the bicyclic semigroup are itself and the group of integers. Here we generalize this result to a broader class of semigroups obtained as variants of the bicyclic semigroup. These semigroups are formed by taking the elements of the bicyclic semigroup under a "sandwich" operation — for a fixed element of $w \in C$, we define the sandwich operation by $x * y = xwy$. We investigate the possible homomorphic images of these variants by analyzing their possible congruence relations, ultimately showing that the homomorphic image of a particular variant is either (a) another variant, (b) the group of integers, or (c) something else which can be described in terms of another variant. In the process, we obtain a number of interesting results about congruence relations on these variants. (Received September 11, 2014)

1106-VJ-1449 **J. Tyrel Winebarger***, 123 Eric Ln, Apt 11, Boone, NC 28607. *Poset Diagrams for θ-Twisted Involutions of Weyl Groups.*

Representation theory of symmetric spaces is an increasingly important in many areas mathematics, including algebraic geometry, number theory, and Lie theory. Given an algebraic group G and an involution θ, we can define the extended symmetric space of G as $R_\theta = \left\{g \in G | \theta(g) = g^{-1}\right\}$. In this talk we use poset diagrams to investigate the structure of the extended symmetric spaces for certain Weyl groups, particularly their decomposition into θ-twisted conjugacy classes. We will present results concerning Weyl groups of type A_n and then extend some of the work to types B_n and F_4. (Received September 13, 2014)

1106-VJ-1493 **Darleen Perez-Lavin***, dperezlavin2207@eagle.fgcu.edu, Fort Myers, FL, and **Erik Insko** and **Pamela Harris**. *Peak Sets of Coxeter Groups of Classical Lie Types.*

In this talk we explore the following: What is the probability that a random element of a Coxeter group has a given peak set? This question was first explored in type A Coxeter groups by Billey, Burdzy, Pal, and Sagan in 2013. In 2014 Castro-Velez, Diaz-Lopez, Orellana, Pastrana, and Zevallos answered this question in type B_n. Using Pascal's triangle and a partition of S_n, we generalize the previous results and to answer this question in the Coxeter groups of types B_n and D_n. (Received September 13, 2014)

1106-VJ-1643 **Stephen M. Adams*** (sa3236@cabrini.edu), Cabrini College, 610 King of Prussia Road, Radnor, PA 19087. *Cross Section Lattices of $\mathcal{J}$-irreducible Reductive Monoids as a Product of Chains.* Preliminary report.

Let M be an irreducible algebraic monoid with reductive unit group G. There exists an idempotent cross section Λ of $G \times G$ orbits that forms a lattice under the partial order $e \leq f \iff GeG \subseteq \overline{GfG}$, where the closure is in the Zariski topology. This cross section lattice is important in describing the structure of reductive monoids. M is said to be $\mathcal{J}$-irreducible when Λ has a unique minimal nonzero element.

In this talk we will describe when the cross section lattice of a $\mathcal{J}$-irreducible monoid will be distributive. We will then describe when this distributive lattice can be written as a product of chains. (Received September 14, 2014)

1106-VJ-1692 **Dong Kyu Kim*** (dongkyu0397@gmail.com), 117-3 Department of Mathmatics, Kyungpook National University, Daegu, 702-701, South Korea, and **Jung Wook Lim** (jwlim@knu.ac.kr), 303-2 Department of Mathematics, Kyungpook National University, Daegu, 702-701, South Korea. *On S-Noetherian domains.*

Let D be an integral domain and S a (not necessarily saturated) multiplicative subset of D. Due to the importance of Noetherian properties, Anderson and Dumitrescu generalized the concept of finitely generatedness and introduced the notion of S-Noetherian domains. They defined D to be an *S-Noetherian domain* if there exist an $s \in S$ and a finitely generated ideal J of D such that $sI \subseteq J \subseteq I$. In this talk, we investigate several properties of S-Noetherian domains. (Received September 15, 2014)

1106-VJ-1721 **Reyes M Ortiz-Albino*** (reyes.ortiz@upr.edu), 1011 Sonsire Chalets, Mayaguez, PR 00682, and **Adolfo G Vargas**. *Some topics on type of relations in the theory of τ-factorizations.* Preliminary report.

A theory of generalized factorization was created by Anderson and Frazier in 2006. The main idea is either to restrict the product into a desired set or to allow elements to multiply only when they are related with respect to a given symmetric relation. For this talk we glance over the main three type of relations studied in the past, present any other type of relation can be created and which type of properties they may have. Will give examples of relations that have good behavior under certain circumstances. (Received September 16, 2014)

1106-VJ-1745 **Benjamin C Gaines*** (bencg@math.duke.edu), Mathematics Department, Duke University, Box 90320, Durham, NC 27708-0320. *The G-Hilbert Scheme and the (0,2)-McKay Correspondence.*

We study first order deformations of the smooth resolutions of orbifolds that are of the form $\mathbb{C}^3/\mathbb{Z}_r$, focusing on the cases where the orbifold has an isolated singularity. We prove a lower bound exists on the number of deformations for any crepant resolution of this orbifold. We also show that this lower bound is achieved when the resolution used is the G-Hilbert scheme, and note that this lower bound can be found using methods from string theory. These methods lead us to a new way to construct the G-Hilbert scheme using the singlet count. (Received September 15, 2014)

1106-VJ-1773 **Nathaniel J Schwartz*** (nschwartz2@washcoll.edu). *On the symmetric k-varieties of orthogonal groups over fields of even characteristic.* Preliminary report.

The characterization and classification of k-involutions of algebraic groups determines much of the structure of the related symmetric k-varieties. Extending results of Dieudonné, Steinberg, and Aschbacher and Seitz and viewing the orthogonal group as a group of matrices, we describe explicitly the automorphisms of order 2. Expanding on recent results by Benim and others, for algebraically closed fields of characteristic not 2, this work substantially completes the characterization of k-involutions of orthogonal group for most fields. Symmetric k-varieties have significance in representation theory, and they also have applications in other areas of mathematics. (Received September 15, 2014)

1106-VJ-1960 **Louis A. Levy*** (louis.levy@bakeru.edu). *An Introduction to Lie Algebra Multipliers.*

Lie algebra multipliers are the Lie algebra analogue of the Schur multiplier from group theory. Since multipliers are abelian Lie algebras, we are interested in finding their dimensions to best understand them. This talk will give a brief overview of Lie algebra multipliers with examples like the one corresponding to the 5-dimensional Heisenberg Lie algebra. (Received September 15, 2014)

1106-VJ-2061 **Miodrag Iovanov** (miodrag-iovanov@uiowa.edu) and **Alex Sistko*** (alexander-sistko@uiowa.edu). *On the Finitely Generated Modules of a Leavitt Path Algebra.* Preliminary report.

The infinite-dimensional, noncommutative algebra $R = \mathbb{K}\langle x, y\rangle/(xy - 1)$ is of basic importance in mathematics, as it provides us with a "universal example" of an algebra containing elements with one-sided inverses. It also arises as the Leavitt path algebra of a relatively simple quiver. In this talk, we discuss the surprisingly rich problem of classifying finitely generated modules over R. We classify semisimple modules and left ideals, and discuss results on the structure of cyclic modules and extensions. Work in progress. (Received September 15, 2014)

1106-VJ-2092 **Carl Edward Looney*** (clooney@uta.edu), 1509 Harwell dr #1215, Arlington, TX 76011. *Non-Assocative Algebraic Structures and Cryptology.*

Associative algebraic structures have been used for constructions of almost all known enciphering systems. However, as shown by Keedwell in 1960's, there exists the possibility of using algebraic structures such as quasigroups, which are not associative, in coding theory, especially in cryptology. In particular m-inverse quasigroups with long inverse cycles have been proven beneficial in coding theory. M-inverse quasigroups (Q,*) have the following property: there exists a permutation J such that for all $a, b \in Q$, $J^m(a * b) * J^(m + 1)(a) = J^m(b)$. Keedwell and Scherbacov have shown the existence of m-inverse loops and quasigroups of some specific small orders. In this talk we discuss the construction of m-inverse quasigroups of orders not shown by Keedwell and Scherbacov. We also show how the method used to construct such algebraic structures can be used to show the nonexistence of such structures for particular orders. (Received September 16, 2014)

1106-VJ-2194 **Chad R Mangum*** (cmangum@niagara.edu). *Free Field Representations of Twisted Toroidal Lie Algebras.*

Lie algebra representation theory has been significant in various areas of mathematics and physics for several decades. The topic of this talk will be representations of twisted 2-toroidal Lie algebras, which are universal central extensions of twisted multi-loop algebras. The loop realization generalizes the familiar realization of affine Kac-Moody algebras. To facilitate our study of the representation theory, we will first discuss an alternative presentation twisted toroidal algebras given via generators and relations. Subsequently, we will discuss a free field representation which is similar to that of a landmark work by Feingold and Frenkel in the case of affine algebras. This is joint work with Dr. Kailash Misra and Dr. Naihuan Jing. (Received September 16, 2014)

1106-VJ-2309 **Harry Jared Warner*** (hjwarner@usc.edu). *The Category of Elementary Subalgebras of a Restricted Lie Algebra.*

For p a prime and Γ a finite group, Quillen's category of elementary abelian p-subgroups of Γ, denoted $\mathcal{E}(\Gamma)$, plays a central role in the cohomology and representation theory of Γ. For $\mathfrak{g}$ a restricted Lie algebra, abelian subalgebras with trivial restriction are the natural analogue to elementary abelian p-subgroups, and are thus referred to as elementary subalgebras. In this talk we will define $\mathcal{E}(\mathfrak{g})$, the category of elementary subalgebras of $\mathfrak{g}$, and in the case that $\mathfrak{g} = \mathrm{Lie}(G)$ for a connected, reductive group G defined over $\mathbb{F}_p$, we will state some results concerning the relationship between $\mathcal{E}(\mathfrak{g})$ and $\mathcal{E}(G(\mathbb{F}_q))$ for q a pth power. If time permits, we will also discuss applications of these results to the study of the G-variety of elementary subalgebras of $\mathfrak{g}$ as defined by Jon Carlson, Eric Friedlander, and Julia Pevtsova. (Received September 16, 2014)

1106-VJ-2353 **Matthew P Gardner Spencer*** (mgardner@holycross.edu). *Power Series under conjugation by the Nottingham Group.*

We consider the action of the Nottingham group over an algebraically closed field of characteristic p on various subsets of power series. We are mainly concerned with power series of the form $x^n + \cdots$ where $p \mid n$. In this case the action has more than one orbit. We give a characterization of the orbits. We further consider whether other actions of the Nottingham group give similar results. (Received September 16, 2014)

1106-VJ-2390 **Andrew F. Misseldine***, Southern Utah University, Mathematics Department, 351 West University Blvd., Cedar City, UT 84720. *Primitive Idempotents of Schur Rings.*

In this talk, we explore the nature of central idempotents of Schur rings over finite groups. We introduce the concept of a lattice Schur ring and explore properties of these kinds of Schur rings. In particular, the primitive, central idempotents of lattice Schur rings are completely determined. For a general Schur ring S, S contains a maximal lattice Schur ring, whose central, primitive idempotents form a system of pairwise orthogonal, central idempotents in S. We show that if S is a Schur ring with rational coefficients over a cyclic group, then these idempotents are always primitive and are spanned by the normal subgroups contained in S. (Received September 16, 2014)

1106-VJ-2526 **R Marshall Lagani*** (marshall.lagani@gmail.com), 450 Penn Ct 5, North Liberty, IA 52317. *Induced Automorphisms of Residuated Function Lattices.*

If $\mathbf{F}$ is any lattice of order preserving functions from lattices L to M, and σ is an an automorphism of $\mathbf{F}$, we say that σ is an *induced automorphism* if there exist mappings in $Aut(L)$ and $Aut(M)$ (σ_L, and σ_M respectively), such that $\sigma = \sigma_M \circ \tau \circ \sigma_L$, where τ is a map in $\mathbf{F}$.

Exploration of the lattice of residuated functions, $Res(L, M)$, illustrates a case where the definition above can be expanded to incorporate induced automorphisms of a second type. For the case when L and M are finite distributive lattices, some results concerning the induced automorphisms of $Res(L, M)$ will be provided and connected to other results found in the literature. (Received September 16, 2014)

General Session on Research in Analysis

1106-VK-29 **George O. Golightly*** (glght9@aol.com), 735 Loop 142, Jacksonville, TX 75766. *Iterated Remainders in the Alternating Harmonic Series.*

If A is a summable sequence, the sequence of remainders in the series summing A is denoted by r(A). In case r(A) is, itself, summable, the sequence r(r(A)) is denoted by $[\mathrm{r}^2](\mathrm{A})$. If A is the alternating harmonic series, each of A, r(A),$[\mathrm{r}^2](\mathrm{A})$,... is alternating, decreasing in magnitude, and has zero limit. Hence, by the Alternating Series Theorem, each of these sequences is summable. Here, we present a simple formula for the sum of these iterated remainders. It is remarked that although the sum of A, r(A)(1), is Ln(2), an irrational number, the sum $[[\mathrm{r}^n](\mathrm{A})](1)$ of all the terms in the sequence $[\mathrm{r}^n](\mathrm{A})$, n=2,3,4,..., is rational. (Received May 01, 2014)

1106-VK-52 **Eyad Massarwi*** (eyadmassarwi@gmail.com), 7048 Mather ave 1S, Chicago Ridge, IL 60415, and **Paul Musial** (pmusial@csu.edu), Chicago, IL 60621. *A Stieltjes Type Extension of the L^r-Perron Integral.*

We explore properties of the L^r-derivates with respect to a monotone increasing Lipschitz function. We then define L^r-ex-major and L^r-ex-minor functions with respect to a monotone increasing Lipschitz function and use these to define a Perron-Stieltjes type integral which extends the integral of L. Gordon. (Received June 02, 2014)

1106-VK-338 **Thomas J. Osler** and **James Rosado*** (jarosado0911@gmail.com), 106 Emily's Lane, Mullica Hill, NJ 08062. *A table of definite integrals from the marriage of power and Fourier series.*

In this paper we show an unusual way to obtain values for definite integrals of the forms $\int_{-\pi}^{\pi} f(x)dx$, $\int_{-\pi}^{\pi} f(x)\cos(nx)dx$, and $\int_{-\pi}^{\pi} f(x)\sin(nx)dx$ where n is a positive integer. Our method is indirect in that we do not start with the integral. The integral is obtained as the end result of a process that did not visualize the integral at the start. We begin with an analytic function, and obtain our integrals by comparing the coefficients of related power series and Fourier series. A table of 36 definite integrals results. Eleven of these can be reproduced by Mathematica or found in familiar tables, while 25 others cannot. These may be new integral evaluations. (Received August 23, 2014)

1106-VK-539 **Yue Zhang*** (yuezhang@uark.edu), Department of Mathematics, SCEN 416, 1 University of Arkansas, Fayetteville, AR 72701. *A variant of Property (P_{n-1}) on smooth pseudoconvex domains.*

We introduce a variant of Property (P_{n-1}) on smooth pseudoconvex domains in $\mathbb{C}^n$ $(n > 2)$ which implies the compactness of the $\overline{\partial}$-Neumann operator N_{n-1}. Our new Property $(P^{\#}_{n-1})$ does not depend on the eigenvalues of the complex Hessian of λ in the definition of the original Property (P_{n-1}), indeed only the diagonal entries in the complex Hessian of λ are involved in our definition of Property $(P^{\#}_{n-1})$. (Received September 16, 2014)

1106-VK-926 **Soumyadip Acharyya*** (sacharyya@crimson.ua.edu) and **Zhijian Wu** (zhijian.wu@xjtlu.edu.cn). *Difference of Two Composition Operators from a Weighted Bergman Space A^p_α to $L^q(\mu)$ when $0 < p \le q < \infty$.* Preliminary report.

Let φ be an analytic self-map of the open unit disc $\mathbb{D}$. The operator $C_\varphi : H(\mathbb{D}) \to H(\mathbb{D})$ defined by $C_\varphi(f) = f \circ \varphi \ \forall f \in H(\mathbb{D})$ is called the Composition Operator with symbol φ. For each $p > 0$ and $\alpha > -1$, the Weighted Bergman Space A^p_α consists of all analytic functions in $L^p(\mathbb{D}, dA_\alpha)$.

We study the difference of two Composition Operators $C_\varphi - C_\psi$ between spaces of analytic functions. A characterization of Boundedness and Compactness(along with an equivalent expression for the essential norm) of $C_\varphi - C_\psi$ from A^p_α to L^q_β, where $0 < p \le q < \infty$ is established by Erno Saukko in 2011. In this talk, we derive the analogous results for $C_\varphi - C_\psi$ acting from A^p_α to $L^q(\mu)$ where μ is any positive Borel measure on $\mathbb{D}$. (Received September 10, 2014)

1106-VK-981 **Joshua Kaminsky** and **Yunfeng Hu*** (yhu@math.wsu.edu), 1610 NE Wheatland Dr, Apt 5, Pullman, WA 99163. *Roughing It: When Convolution isn't Smooth.*

It's a well known result that for a smooth function ϕ, and another function f, $\phi * f$ is smooth even if f is quite bad. However, even in cases where neither ϕ nor f is smooth, convolution is still a smoothing operator. In particular, we can find f and g such that $f * g$ is smooth even when f and g are characteristic functions. We'll also talk more generally about the case where f and g are characteristic functions on sets with smooth boundaries. (Received September 09, 2014)

1106-VK-995 **Marcos David Lopez*** (lopezms@mail.uc.edu), Department of Mathematics, 4199 French Hall West, 2815 Commons Way, Cincinnati, OH 45221-0025, and **James T Gill** (jgill5@slu.com), Department of Mathematics and Computer Sci, Ritter Hall 129, 220 N. Grand Blvd., St. Louis, MO 63103. *Discrete Approximations of Metric Measure Spaces of Controlled Geometry.*

Let (X, d) be a metric space with a doubling measure μ. If (X, d, μ) is endowed with a Poincaré type inequality, then it becomes an element from an essential class of metric spaces in the study of Sobolev spaces. Often, it is difficult to verify that an arbitrary measure metric space, (X, d, μ), carries a Poincaré type inequality. I will present a method to discretize the space (X, d, μ) while preserving its doubling property. I will then present a necessary and sufficient condition for (X, d, μ) to carry a $(1, p)$-Poincaré Inequality involving a discretized $(1, p)$-Poincaré inequality on the constructed discretized space. This condition relies on important results due to Cheeger and Koskela, and the ability of a series of discretized spaces to approximate (X, d, μ). These results are due to joint work with James Gill. (Received September 09, 2014)

1106-VK-1170 **Morteza Shafii-Mousavi*** (mshafii@iusb.edu), Indiana University South Bend, PO Box 7111, South Bend, IN 46634. *Functional Dimension of Solution Space of Differential Operators of Constant Strength.*

Let P(D) be a differential operator with constant coefficients and N = { u : P(D)u = 0 } to be the solution space of P(D) furnished with the uniform convergence topology on compact subsets. It is known that: 1) P(D) is hypoelliptic iff N is nuclear; 2) P(D)is hypoelliptic iff the functional dimension of N is finite; 3) P(D) is hypoelliptic iff it is d-hypoelliptic where d = (d1, ...,dn) is the Gevrey regularity of the solutions. Furthermore the author proved that P(D) is d-hypoelliptic iff the functional dimension dfN = d1+...+dn+1-mindj. I will discuss the generalization of these properties to operators P(x , D) of constant strength. The functional dimension is the entropy of the solution space. (Received September 11, 2014)

1106-VK-1212 **Yevgeniy Kostrov** and **Zachary A. Kudlak***, Department of Mathematics, Monmouth University, 400 Cedar Ave, West Long Branch, NJ 07764. *On A System of Rational Difference Equations with Nonnegative Periodic Coefficients.* Preliminary report.

In this preliminary report, we investigate the global stability, periodic character, and the boundedness nature of the solutions of several special cases which are contained in the following system of difference equations: $x_{n+1} = \frac{\alpha_n^{(1)}}{B_n^{(1)}x_n+y_n}$, $y_{n+1} = \frac{\alpha_n^{(2)}+\beta_n^{(2)}x_n+\gamma_n^{(2)}y_n}{A_n^{(2)}+B_n^{(2)}x_n+C_n^{(2)}y_n}$, $n \geq 0$, where initial conditions x_0 and y_0 are nonnegative and not both zero, and where the coefficients form nonnegative, periodic sequences such that the denominators are always positive. (Received September 11, 2014)

1106-VK-1498 **Javad Namazi*** (namazi@fdu.edu), 285 Madison Avenue, Madison, NJ 07940. *A Note on Riesz Means.* Preliminary report.

The Riesz mean $\sigma_T^{\alpha,\gamma}$ is defined as

$$\sigma_T^{\alpha,\gamma} = (\frac{\alpha\gamma}{T})\int_0^T (1-(\frac{t}{T})^\gamma)^{\alpha-1}(\frac{t}{T})^{\gamma-1}s_t f(x)dt, \quad T>0$$

where $t>0, \alpha>0$, $\gamma>0$, and $s_t f(x)$ is the Dirichlet integral of $f \in L^p(R)$, the Lebesgue space for $0<p<\infty$. We discuss some properties of the Riesz means and its special relationship with the Hardy spaces $H^p(R)$. (Received September 13, 2014)

1106-VK-1775 **G Brock Williams** and **Olivia Isabella Orrantia-Kotowski*** (olivia.orrantia@ttu.edu). *Circle Packing Random Triangulations.* Preliminary report.

The deep connection between conformal maps and discrete maps from one circle packing to another have been an object of study since Thurston's pioneering work in the 1980s. Far less well understood is the nature of maps from a random triangulation to a circle packing for that triangulation. We will describe our work analyzing such maps. (Received September 15, 2014)

1106-VK-1878 **Chizuko Iwaki*** (iwaki@uark.edu). *Strong Stein Neighborhood Bases for Nonsmooth Pseudoconvex Domains.*

In 1979, Dufresnoy showed that the existence of a good Stein neighborhood base for $\Omega \subset \mathbb{C}^n$ implies that one can solve the inhomogeneous Cauchy-Riemann equations in $C^\infty(\bar{\Omega})$, even if the boundary of Ω is only Lipschitz. In this talk, sufficient conditions for the existence of a good Stein neighborhood base on a Lipschitz domain are shown. This talk is part of my thesis research with Phil Harrington. (Received September 15, 2014)

1106-VK-1930 **Waleed K. Al-Rawashdeh*** (walrawashdeh@mtech.edu), Montana Tech, 1300 West Park Street, Butte, MT 59701. *Composition Operators on Weighted Bergman and S^p Spaces.*

Let φ be an analytic self-map of open unit disk $\mathbb{D}$. The operator given by $(C_\varphi f)(z) = f(\varphi(z))$, for $z \in \mathbb{D}$ and f analytic on $\mathbb{D}$ is called composition operator. For each $p \geq 1$, let S^p be the space of analytic functions on $\mathbb{D}$ whose derivatives belong to the Hardy space H^p. For $\alpha > -1$ and $p>0$ the weighted Bergman space A_α^p consists of all analytic functions in $L^p(\mathbb{D}, dA_\alpha)$, where $dA_\alpha(z) = \frac{(1+\alpha)}{\pi}\left(1-|z|^2\right)^\alpha dA(z)$ is the normalized weighted area measure.

In this talk, we characterize boundedness and compactness of composition operators act between weighted Bergman A_α^p and S^q spaces, $1 \leq p, q < \infty$. Moreover, we give a lower bound for the essential norm of composition operator from A_α^p into S^q spaces, $1 \leq p \leq q$. (Received September 15, 2014)

1106-VK-2030 **Jim Cockreham*** (jcockreham@uidaho.edu). *The Metric Entropy of q-hulls and the Fractional Integral.*

This talk will present two new results. The first is an asymptotic result on the metric entropy of the q-hull of a precompact set K, where $0<q<1$. The second result is the metric entropy of $G_\alpha = \{I_\alpha f | f \in \mathcal{F}\}$, where I_α denotes the *fractional integral* and the entropy of the family $\mathcal{F}$ is given. We will then apply this result to the family of *s-concave functions*. (Received September 15, 2014)

1106-VK-2081 **Raena B King*** (rking2@cbu.edu), Christian Brothers University, Department of Mathematics, 650 E Parkway S, Memphis, TN 38104. *Generalized bi-circular projections and averages of isometries on Hardy spaces.*

Generalized bi-circular projections (GBPs) are the projections, P, such that for some $\lambda \neq 1$ with $|\lambda| = 1$, $P + \lambda(I - P)$ is an isometry. We consider the generalized bi-circular projections on certain Hardy spaces. Since many GBPs are given by the average of an identity and a reflection, we also find when the average of two isometries gives a projection. (Received September 15, 2014)

1106-VK-2112 **Sarah Charley*** (src210@lehigh.edu), 14 E. Packer Ave, Bethlehem, PA 18015, and **Vladimir Dobric** and **Rob Neel**. *Constructing Prescale Functions via the Dilation Equation for Measures.*

One way to understand the dilation equation is through a measure theoretic approach. We consider a general signed measure which satisfies the dilation equation for measures:

$$\mu(M^{-1}A) = \sum_{k \in F} p_k \mu(A - k)$$

for any Borel set A and a finite set F. We are able to explicitly find the support of the measure μ using Dirac delta measures associated with the dilation equation. The prescale function can be computed by an iterative process starting on the support.

For a specific choice of M, the set of points in the plane of the form $\sum_{j=1}^{\infty} M^{-j} p_j$, with $p_j \in \{(0,0),(1,0)\}$ is called the Twin Dragon. Integer lattice shifts of the Twin Dragon tile the plane. We define a new measure ν based on μ, which is defined only on the Twin Dragon: $\nu(A) = \sum_{k \in F} \mu(A - k)$. By creating algebraic equations on our coefficients p_j and using the Radon-Nikodym Theorem, we are able to characterize the prescale functions. Using properties of the dilation equation for measure and the definition of ν, we will show that ν must be a constant multiple of Lebesgue measure on the Twin Dragon. In fact, we will show that $\nu(A) = \nu(T)\lambda(A)$, where T is the Twin Dragon. (Received September 15, 2014)

1106-VK-2267 **D Brian Walton*** (waltondb@jmu.edu), 60 Bluestone Dr, MSC 1911, Roop Hall 110, Harrisonburg, VA 22807. *Maximum likelihood analysis of transposable element age distributions using a master copy model of evolution.* Preliminary report.

Transposable elements (TEs) are genetic elements in DNA that self-replicate and insert copies of themselves to other locations in the genome. This process often has a high failure rate so that copies are dead on arrival. Nonfunctional copies generate sequences subject to neutral evolution and thereby provide artifacts that document the history of TE activity. Using the master copy model of evolution, we establish a stochastic model of TE production and evolution that facilitates the calculation of likelihood for observed sequences based on parameters for the age distribution and the rates of evolutionary events of substitutions, insertions and deletions. This report discusses the numerical implementation and results of these models and their application to genome analysis. (Received September 16, 2014)

1106-VK-2396 **Rachel A. Neville***, Department of Mathematics, 1874 Campus Delivery, Fort Collins, CO 80523. *Patterns in Persistence: Persistent Homology of Chaotic Dynamical Systems.* Preliminary report.

Persistent homology is a recently explored tool in computational topology that captures information regarding the longevity or size of topological features of geometric objects or discrete data. In this project, persistent homology is applied to discrete and continuous functions as a means of examining connected components of level sets of the function. Information is recorded in a persistence diagram. This provides a novel tool for computationally examining dynamical systems. When the persistence diagram is generated for an orbit of the logistic map, an interesting pattern arises in the persistence diagram in the periodic regimes that surprisingly continues in the chaotic regime. This pattern will be discussed and extended to other systems, including continuous systems. (Received September 16, 2014)

1106-VK-2544 **Gokul R Kadel***, Cameron University, Department of Mathematical Sciences, 2800 W Gore Blvd, Lawton, OK 73505, and **Kit C Chan**, Bowling Green State University, Department of Mathematics and Statistics, Bowling Green, OH 43402. *Invertible Chaotic Extensions of Operators on Hilbert Subspaces.*

For an operator $A : M \to M$ on a subspace of an infinite dimensional Hilbert space H, Chan and Turcu showed that there exists an operator $T : H \to H$ that is chaotic and $T|_M = A$. Such an extension exists only if the supspace M has an infinite codimension in H, i.e., $\dim(H/M) = \infty$. Their extension T has a nontrivial kernel and therefore cannot be invertible. In this talk, we present a result that proves the existence of an invertible operator $T : H \to H$ that is chaotic and extends A. Moreover, we give a necessary and sufficient condition for the existence of an invertible chaotic extension of an operator on the Hilbert subspace. (Received September 16, 2014)

1106-VK-2601 **Arindam Roy*** (roy22@illinois.edu) and **Nicolas Robles**. *Moments of the average of a generalized Ramanujan sum.*

The moments of the average of a generalized Ramanujan sums are derived. This generalization was introduced by Cohen. We will also obtained some improvements of some previous results on the moments of the average of the Ramanujan sums. Related explicit formulae involving the non-trivial zeros of the Riemann zeta-function are also derived. This is a joint work with N. Robles. (Received September 16, 2014)

1106-VK-2602 **John Joseph Vastola*** (johnvastola@knights.ucf.edu), 1190 Lake Rogers Cir, Oviedo, FL 32765, and **Costas J Efthimiou** (costasatucf@gmail.com). *Systematically evaluating sums using integral transforms, with applications to statistical and quantum physics.*

Evaluating sums analytically is a problem that is easy to pose and to give approximate solutions to, but that is difficult to exactly solve in general. Many of the results that are known are byproducts of Fourier analysis, which requires guessing that a series corresponds to a function; for obvious reasons, this is undesirable. A method of evaluating sums using integral transforms is proposed which can reproduce many results obtained using other techniques. In particular, representing polynomials as Laplace transforms gives some nontrivial exact results. Some applications of the method are demonstrated, and extensions using integral representations of frequently appearing functions are suggested. One useful representation of the gamma function is supplied, and used to provide both well-known and more obscure results. Interestingly, the application of this integral representation to evaluating sums suggests the introduction of a novel integral transform, which itself can be used to evaluate sums. Some of the transform's properties are given, and its usefulness in other areas (like solving differential equations) is touched upon. Some physical problems involving the partition functions of statistical mechanics, and some infinite sums appearing in quantum mechanics, are considered. (Received September 16, 2014)

1106-VK-2747 **Jesse B Freeman*** (jbf1@williams.edu), 11 Meadow Street, Williamstown, MA 01267. *On the vanishing of L-functions at the central point through the method of Fredholm determinants.* Preliminary report.

The zeta function is an L-function whose zeros encode information about the primes. Similarly, the zeros of L-functions associated to elliptic curves, modular forms, and Dirichlet characters (among others) contain information about those objects. In this vein, the order of vanishing at the point $s = 1/2$ is particularly important.

We can study that order of vanishing using a statistic called 1-level density. It is an appealing statistic because of the Katz-Sarnak conjecture that the average one level density of a family of L-functions can be calculated without knowing any zeros in the family. Confirmed for certain families of holomorphic cusp forms, the conjecture states that the average one level density of a family depends on the family's symmetry group and a chosen test function. It is then natural to ask which test function gives the best results on vanishing.

Iwaniec, Luo, and Sarnak found the optimal test functions whose Fourier transforms are supported in $(-2, 2)$. We generalize their analysis of Fredholm operators to find the optimal test function for any finite interval of support. Additionally, we determine the optimal test functions for the 2 and higher level densities, which yield better results on order vanishing at the central point. (Received September 16, 2014)

General Session on Research in Applied Mathematics

1106-VL-1 **Erwin Suazo*** (esuazo@asu.edu), Physical Sciences, A-Wing — P.O. Box 871804, Tempe, AZ 85281, and **Primitivo B. Acosta-Humanez** and **Sergei K. Suslov**. *Riccati-Ermakov systems and closed solutions for the degenerate parametric oscillator.*

As a nice application of differential Galois theory we present how we can construct explicit solutions for the propagator for a generalized harmonic oscillator. This has applications describing the process of degenerate parametric amplification in quantum optics as well as light propagation in a nonlinear anisotropic waveguide. Our solutions are conditioned on solving nonlinear systems that we have called Riccati-Ermakov systems, and we show several examples of solutions of this kind of systems. Our solutions will be useful to test standard numerical methods used. Finally, using Riccati-Ermakov systems we show how we can construct soliton solutions for a nonautonomous nonlinear Schrödinger equation.

References:
[1] P. B. Acosta-Humanez and E. Suazo, Liouvillian propagators, Riccati equation and differential Galois theory, J. Phys. A: Math. Theor. 46 (2013) 45520. (Received April 16, 2014)

1106-VL-25 **Amir Zareian Jahromi*** (amir.zareianjahromi@gmail.com), Tehran, Iran. *A transport model for thermodynamic estimation of cryogenic hydrogen.*

Hydrogen is a foundation element of the universe and has attracted attention as a key of the solution for the energy and environmental problem. However, liquid hydrogen shows strange behavior as compared to other field due to the nuclear quantum effect. Because of this effect it is difficult to comprehend the thermodynamic and transport properties of liquid hydrogen by using the usual method. Therefore several methods have been proposed to reproduce the time evolution of the molecules in which the nuclear quantum effect contributes to their behavior. However, since the previous studies are still verification stage of the methods, an effect of the nuclear quantum nature of hydrogen and its mechanism on the thermodynamics and transport properties have not been clarified in details. Especially, how the quantum nature would effect on the energy transfer in molecular scale has not been clarified. In this study, therefore, we investigated the effect of this quantum nature and its mechanism on the thermodynamics and transport properties of cryogenic hydrogen using classical molecular dynamics methods. We applied Centroid Molecular Dynamics methods, Ring Polymer Molecular Dynamics methods, and Maximum Entropy numerical analytic continuation methods. (Received April 28, 2014)

1106-VL-199 **Rachel Elizabeth TeWinkel*** (tewinke2@uwm.edu), UW-Milwaukee, Department of Mathematical Sci Rm E403, 3200 N Cramer St, Milwaukee, WI 53211-3029. *Epidemic Modeling with Optimal Controls in a Setting with Limited Resources and Spatial Dynamics.* Preliminary report.

A Susceptible-Infected-Recovered (SIR) epidemic model is presented with the assumption of there being limited resources for the mitigation of the epidemic. We discuss the optimal controls of vaccination and isolation on the system under the assumption that the vaccination does not offer perfect immunity. Simulation results show the possible effects of the optimal bang-bang controls as the epidemic progresses. A cellular automata (CA) model with similar assumptions is then described and similar simulations are produced with the addition of the spatial component. A comparison between the results of the SIR model and the CA model highlights the need for careful consideration of spatial dynamics and assumptions in these models. We show that there are cases where the simulations for the SIR model show significantly more individuals affected by the epidemic than the corresponding simulations for the CA model. We give a brief outline of how changing the assumption that isolation perfectly stops the spread of disease can change the outcome of the epidemic simulations in both the SIR model and the CA model. (Received September 16, 2014)

1106-VL-230 **N. S. Hoang*** (nhoang@westga.edu), 1601 Maple Street, Carrollton, GA 30118. *On node distributions for interpolation and spectral methods.*

A scaled Chebyshev node distribution is studied in this paper. It is proved that the node distribution is optimal for interpolation in $C_M^{s+1}[-1,1]$, the set of $(s+1)$-time differentiable functions whose $(s+1)$-th derivatives are bounded by a constant $M > 0$. Node distributions for computing spectral differentiation matrices and integration matrices are proposed and studied. Numerical experiments show that the proposed node distributions can yield results with higher accuracy than the most commonly used Chebyshev-Gauss-Lobatto node distribution. (Received August 13, 2014)

1106-VL-263 **Jack A. Ryan*** (jaryan@noctrl.edu). *Recognition of Textural Differences in Infrared and Ultraviolet Imagery Using Fractal Characteristics.*

This project utilized an algorithm written by Troy Thielen that is used to estimate the fractal dimension (complexity) and lacunarity (spread) of gray-scale images. New ultraviolet and infrared images were taken throughout the project and analyzed using this algorithm. The fractal characteristics of these images were then analyzed to recognize textural differences within imagery, a useful method when attempting to recognize objects or locate targets. Differences between ultraviolet, infrared and visual imagery were analyzed, and additional implications of the recognition of textural differences were explored. (Received September 15, 2014)

1106-VL-574 **Xinyao Yang*** (xywp8@mail.missouri.edu), 701 S. Providence Road, Apt 1-I, Columbia, MO 65203. *Stability for Perturbations of a Steady State at the One Dimensional Case.*

In this presentation, I will discuss the stability of perturbations of a two-dimensional dynamical system. I will also discuss the convective stability of the solution to the system bounded in time with respect to an expoentially weighted norm. (Received September 02, 2014)

1106-VL-597 **Emese A. Kennedy*** (ealipcse@ncsu.edu) and **Hien T. Tran**. *Real-Time Implementation of Nonlinear Control Methodologies for a Single Inverted Pendulum.*

The single inverted pendulum (SIP) system is a classic example of a nonlinear system. It is considered as one of the most popular benchmarks of nonlinear control theory. Many nonlinear methods have been proposed for the swing-up and stabilization of a self-erecting inverted pendulum, however, most of these techniques are too complex and impractical for real-time implementation. We will discuss the real-time implementation of two feedback control methodologies for the nonlinear SIP system. Both techniques are based on a numerical approximation to the solution of the Hamilton-Jacobi-Bellman (HJB) equation. The first method uses power series to approximate the solution to the HJB equation, while the second method applies the power series expansion to the related state-dependent Riccati equation (SDRE) instead of solving the HJB equation itself. (Received September 03, 2014)

1106-VL-762 **Mohamed H Amsaad*** (mamsaad@math.wvu.edu), West Virginia University. *Well-defined Lagrangian flows for absolutely continuous curves of probabilities on the real line.*

In this talk I will present some results of analyzing the Lagrangian description of absolutely continuous curves of probability measures on the real line, which are mainly from my joint work with A. Tudorascu of West Virginia University. Whereas each such curve admits a Lagrangian description as a well-defined flow of its velocity field, further conditions on the curve and/or its velocity are necessary for uniqueness. We identify some of such conditions that ensure that the only flow map associated to the curve consists of a time-independent rearrangement of the generalized inverses of the cumulative distribution functions of the measures on the curve. At the same time, our method of proof yield uniqueness within a certain class for the curve associated to a given velocity, i.e. they provide uniqueness for the solution of the continuity equation within a certain class of curves. (Received September 06, 2014)

1106-VL-776 **Brent Oneil Young*** (bojy77@gmail.com), 2550 NC Hwy 242 South, Benson, NC 27504. *Landau Damping in Relativistic Plasmas.*

We examine the phenomenon of Landau Damping in relativistic plasmas via a study of the relativistic Vlasov-Poisson system (rVP) on the torus for initial data sufficiently close to a spatially uniform steady state. We find that if the steady state is regular enough (essentially in a Gevrey class of degree in a specified range) and that the deviation of the initial data from this steady state is small enough in a certain norm, the evolution of the system is such that its spatial density approaches a uniform constant value sub-exponentially fast (i.e. $\exp(-C|t|^{\overline{\nu}})$ for $\overline{\nu} \in (0,1)$). We take as *a priori* assumptions that solutions launched by such initial data exist for all times and that the various norms in question are continuous in time. In addition, we must assume a kind of "reverse Poincaré inequality" on the Fourier transform of the solution. In spirit, this assumption amounts to the requirement that there exists $0 < \varkappa < 1$ so that the mass in the annulus $\varkappa \leq |v| < 1$ for the solution launched by the initial data is uniformly small for all t. Typical velocity bounds for solutions to rVP launched by small initial data (at least on $\mathbb{R}^6$) imply this bound. (Received September 06, 2014)

1106-VL-869 **Nino Khatiashvili*** (ninakhatia@gmail.com), Iv.Javakhishvili Tbilisi State University, 2., University St. 0143TBILISI, Rep.of GEORGIA, 0143 TBILISI, Rep of Georgia. *On the Quantum Billiard in the Hexagonal Type Areas.* Preliminary report.

In the paper quantum billiard in the hexagonal type areas such as hexagon with the hexagonal hall,hexagonal rug, hexagonal flower and hexagonal prismoid is studied.The process is described by the Helmholtz Equation with the homogeneous boundary condition. The problem is investigated by means of the conformal mapping and partial differential equation.The Helmholtz Equation is transformed to the equation of the elliptic type. One parameter of the mapping is chosen sufficiently small, the initial equation is simplified and replaced by the approximate elliptic equation in the rectangle with the homogeneous boundary conditions. The asymptotic solutions of this equation are obtained. The spectrum and the corresponding eigenfunctions are find near the boundary of the rectangle. The wave functions are find in terms of the Bessel's functions. The results are applied for the estimation of the energy levels of electrons in graphene. (Received September 08, 2014)

1106-VL-1011 **Yuan Liu***, 619 Red Cedar Road, Department of Mathematics, Michigan State University, East Lansing, MI 48824. *high order parametrized maximum-principle-preserving and positivity-preserving weno schemes on unstructured meshes.*

We will talk about the generalization of the maximum-principle-preserving (MPP) flux limiting technique developed in [Z. Xu, Math. Comp., (2013)] to develop a class high order MPP finite volume schemes for scalar conservation laws and positivity-preserving (PP) finite volume WENO schemes for compressible Euler system on two dimensional unstructured meshes. The key idea of this parameterized technique is to limit the high order schemes towards first order ones which enjoy MPP property, by decoupling linear constraints on numerical fluxes. Error analysis on one dimensional non-uniform meshes is presented to show the proposed MPP schemes can maintain high order of accuracy. Similar approach is applied to solve compressible Euler systems to obtain high order positivity-preserving schemes. Numerical examples coupled with third order Runge-Kutta time integrator are reported. (Received September 09, 2014)

1106-VL-1026 **Jason Karl Davis*** (jdavis8@ucmerced.edu), 5200 N Lake Rd, Merced, CA 95343, and **Suzanne S Sindi** (ssindi@ucmerced.edu), 5200 N Lake Rd, Merced, CA 95343. *Solution of a Recurrence Relation Governing Prion Aggregation and Fragmentation.*

Prion proteins are responsible for a variety of neurodegenerative diseases in mammals such as Creutzfeldt-Jakob disease in humans and "mad-cow diease" (Bovine Spongiform Encephalopathy or BSE) in cattle. We provide the standard mathematical derivation of the nucleated polymerization model (Masel et al, 1999), but then solve the recurrence relation exactly at steady-state using a generating function rather than the standard approach of resorting to a continuous approximation and solving the corresponding PDE. We then demonstrate the uniform convergence of the exact solution to the continuous relaxation in the large, average aggregate-size limit. (Received September 09, 2014)

1106-VL-1039 **Shiyun Tang*** (tsy@ou.edu), **Xiangming Xiao**, **Maria C.A. Leite**, **Meijun Zhu**, **Yueling Shu** and **Tao Chen**. *Modeling Seasonal Dynamics and Spatial Patterns of Seasonal Influenza at the Global Scale.* Preliminary report.

Based on the hypothesis that climate - influenza virus - human interactions determine the seasonal dynamics of influenza transmissions in a year at various geographical regions, we introduce an approach to analyze seasonal dynamics and inter-annual variation of influenza transmission across latitudinal gradient. In particular, we will discuss mathematical epidemiological models (SEIRS) that incorporate three ecology-based response functions: influenza virus survival and human susceptibility response to air temperature, and influenza virus transmission response to specific humidity. Results for single cities as well as global scale simulation will be presented. Interestingly, the model reproduce not only the reported two peaks (winter - and summer peaks) of influenza in subtropical region, but also the observed temporal pattern of flu in temperate regions (one winter peak). The global simulations results will illustrate how the model can help to explore possible mechanism for the global circulation of the influenza and to better understand the circulation over the globe. (Received September 16, 2014)

1106-VL-1048 **Mihhail Berezovski*** (mihhail.berezovski@gmail.com), Department of Mathematical Sciences, Worcester Polytechnic Institute, 100 Institute Rd, Worcester, MA 01609. *Numerical simulation of wave propagation in dynamic materials.* Preliminary report.

Dynamic materials are artificially constructed structures (like metamaterials) which may vary their characteristic properties in space or in time, or both, by an appropriate arrangement or control. These controlled changes in time can be provided by the application of an external (non-mechanical) field, or through a phase transition. Such materials exhibit very unusual behavior. The characteristic phenomenon for dynamic materials is wave propagation because it is also space and time dependent. As a simple example of the complex behavior of dynamic materials, the one-dimensional elastic wave propagation is studied numerically in periodic structures whose properties (mass density, elasticity) can be switched suddenly in space and in time. It is shown that dynamic materials have the ability to dynamically amplify, tune, and compress initial signals over a wide range of carrier frequencies. The thermodynamically consistent high-resolution finite-volume numerical method was successfully applied to the study of the behavior of dynamic materials. The extended analysis of the influence of inner reflections on the energy accumulation and concentration in the dynamic materials is presented. (Received September 10, 2014)

1106-VL-1066 **Andy J Johnson** and **Dillon M Brown*** (dmb101@francis.edu), Ebensburg, PA 15931. *Finding Roots of a Non-Linear Function using The Brown-Johnson Method.*

The Brown-Johnson Method was developed by combining aspects of the following methods: Bisection Method, Newton's Method, and Secant Method. Secant and tangent lines are used to restrict the range that the root could lie within, and then the Bisection Method is used approximate the root. The Brown-Johnson method converges at almost the same rate as Newton's method, and also guarantees convergence when given an appropriate initial interval. (Received September 10, 2014)

1106-VL-1136 **Noah S. Daleo*** (nsdaleo@ncsu.edu), **Jonathan D. Hauenstein**, **Dhagash Mehta** and **Florian Dörfler**. *Equilibria and stability analysis in applications via numerical algebraic geometry.*

In applications, we often encounter systems of nonlinear ordinary differential equations: $\dot{\mathbf{x}} = F(\mathbf{x})$. In the case that F is a system of polynomials, we demonstrate the use of numerical homotopy continuation techniques to compute all equilibria of the system. We then investigate models in which F is not polynomial, but such that a corresponding system of polynomials may be used to locate equilibria. Once all equilibria are computed, we analyze their stability to identify steady state solutions. This numerical approach facilitates the study of thousands of equilibria occuring at different sizes of systems and at various parameter choices for the original system. (Received September 10, 2014)

1106-VL-1178 **Jeffrey Alan Willert*** (jaw@lanl.gov), Theoretical Division - MS B216, Los Alamos National Laboratory, Los Alamos, NM 87545. *Choosing a Nonlinear Solver for the Moment-Based Accelerated Thermal Radiative Transfer Algorithm.*

Recent algorithm design efforts for kinetic equations have included a class of highly-efficient methods referred to as Moment-Based Accelerators (MBAs), or High-Order/Low-Order (HO-LO) methods. For the Thermal Radiative Transfer problem, a MBA predictor-corrector algorithm has been designed in which a nonlinear reduced-phase-space problem must be solved twice per timestep. Traditionally, this nonlinear system has been solved using a Jacobian-Free Newton-Krylov (JFNK) approach, however this method is known to struggle for certain problem regimes. In this talk, we explore alternative modern nonlinear solvers including Anderson Acceleration. We conclude the talk with a comparison of JFNK and Anderson Acceleration and provide computational timing results. (Received September 11, 2014)

1106-VL-1200 **Mary O'Driscoll*** (odriscol.mary@uwlax.edu), UW-L Mathematics Department, La Crosse, WI 54601, and **James Peirce**. *Investigating the Dependence of Transmission Rate to Water Temperature in a Host-Parasite System.* Preliminary report.

Every year, thousands of waterfowl around the upper Mississippi River are dying from parasites transmitted to them through an invasive species of snail. The parasite species exhibit temperature-dependent transmission patterns with no transmission occurring when temperatures either fall below or exceed certain thresholds. The transmission window overlaps the waterfowl's seasonal migrations. The purpose of this study was to determine how the temperature of the water affects the transmission rate of the parasite. First, we moved the range and the location of the temperature window for parasite transmission. Second, we created an algorithm that defined the transmission parameters based upon the length of time temperature spends above or below a known threshold. In both studies, the size of the infected host populations depended on the temperature window and accrued time. Results reinforce biological observations and emphasize why it is important to study transmission at various temperatures in the laboratory. (Received September 11, 2014)

1106-VL-1374 **David C. Carothers*** (carothdc@jmu.edu), Dept of Mathematics and Statistics, James Madison University, MSC 1911, Harrisonburg, VA 22807. *Polynomial differential equations and removable singularities.* Preliminary report.

We use basic Gröbner basis techniques to provide an alternative characterization for a class of analytic functions considered by Harley Flanders (*Functions not satisfying implicit, polynomial ODE*, J. Differential Equations 240). This class includes functions such as f with $f(t) = \frac{e^t - 1}{t}$, $f(0) = 1$. Implications and further applications emerging from this characterization will be considered. (Received September 15, 2014)

1106-VL-1377 **Xinli Wang*** (xwang@uscupstate.edu), 800 University Way, Spartanburg, SC 29303, and **German Drazer** (german.drazer@rutgers.edu), 98 Brett Rd, Piscataway, NJ 08854. *Biased transport of Brownian particles in a serpentine channel.*

We consider the biased transport of Brownian particles in a serpentine channel. Particles are confined either by solid walls or by a parabolic potential. The asymptotic method is applied to investigate the macro transport properties (the mobility and the effective diffusion coefficient) in a narrow channel. Our results show that both quantities are independent on the Peclet number. Furthermore, we show that the numerical results from the Brownian dynamic simulation match the analytical results very well. (Received September 12, 2014)

1106-VL-1388 **Thomas Bellsky*** (thomas.bellsky@maine.edu), Department of Mathematics and Statistics, University of Maine, Neville Hall 326, Orono, ME 04469. *Stability of localized structure for a semi-arid climate model.*

This talk will discuss the interaction of pulses in coupled reaction-diffusion systems, and the application of such systems in modeling the stability of vegetative patterns in semi-arid climates. For a particular family of fast-slow, weakly-damped reaction-diffusion systems, we rigorously derive laws of motion for multi-pulses. Our main result rigorously demonstrates the stability of the manifold of pulse solutions. (Received September 12, 2014)

1106-VL-1415 **Fatma N. A. Mohamed*** (fmohamed@math.wvu.edu), West Virginia University. *Thin viscous films: thinning driven by surface-tension energy dissipation.* Preliminary report.

In this talk I will present some results for thin viscous films, which are mainly from my joint work with A. Tudorascu of West Virginia University. We study the evolution of a thin film of fluid modelled by the lubrication approximation for thin viscous films. We prove existence of (dissipative) strong solutions for the Cauchy problem when the subdiffusive exponent ranges between 3/8 and 2; then it follows that these solutions tend to zero at rates matching the decay of the source-type self-similar solutions with zero contact angle. Finally, we introduce the weaker concept of dissipative mild solutions and we show that in this case the surface-tension energy dissipation is the mechanism responsible for the H^1-norm decay to zero of the thickness of the film at an explicit rate. (Received September 12, 2014)

1106-VL-1420 **Hamid Semiyari*** (semiyahx@jmu.edu), Department of Mathematics and Statistics, 305 Roop Hall, MSC 1911, James Madison University, Harrisonburg, VA 22807. *A Numerical Solution to boundary Value problems and Volterra Integrals.* Preliminary report.

G. Edgar Parker and James Sochacki, of James Madison University (JMU) developed a method based on Picard's iteration method to solve ordinary differential equations (ODEs). The method is an algorithm that generates Maclaurin series solutions to Initial Value Problems (IVPs). The method converts an IVP into a system of first order ODEs, where the right hand side is a polynomial. The advantage of this method is that the method requires only addition and multiplication which makes it a good choice for computation. We demonstrate this method for Two Point Boundary Value Problems (ODE) and Volterra Integral Equations. (Received September 12, 2014)

1106-VL-1423 **Stephanie A. Blanda*** (sab466@psu.edu), Department of Mathematics, The Pennsylvania State University, University Park, PA 16802. *The Interface of Two Fluids Under a Shear Flow.* Preliminary report.

The generation of waves by wind has long been a topic of interest. However, it has only been in the past 50 years or so that significant progress has been made in understanding the effect of wind on water waves. Despite this progress, there is still much we do not understand about the interaction. Our goal is to look at dynamics that have been previously ignored and see if they help us better predict wave growth. In particular, we focus on the effect of viscosity on the overall growth/decay rate of waves. Here we will consider the coupled air/water system as a viscous 2-layer system. In this talk, I will describe the derivation of the equations for the linear theory dealing with the interface of two immiscible, incompressible, viscous fluids under a shear flow and discuss the numerical methods we have used to solve these equations. (Received September 12, 2014)

1106-VL-1458 **Jordan L Torgunrud*** (jordan.torgunrud@my.minotstateu.edu) and **Narayan Thapa** (narayan.thapa@minotstateu.edu). *On the Numerical Treatment of Water Pollution Model.*

Water quality management is a critical component of overall integrated water resources management. Mathematical models are now vital tools in water resources management and are currently applied for the solution of environmental problems around the globe. In this talk, a second order partial differential equation model as an Initial Boundary Value Problem (IBVP) will be developed for the estimation of water pollution. Both analytical and numerical solutions of the model will be presented. (Received September 13, 2014)

1106-VL-1554 **Titus J. O. Aminer*** (titusaminer@yahoo.com), JOOUST, P. O. Box 210-40601, Bondo, +254, Kenya. *Lie Symmetry Solution of Fourth Order Nonlinear Ordinary Differential Equation.*

The equation $F(x, y, y', y'', y''', y^{(4)}) = 0$ is a one-space dimension version of wave equation. Its solutions can be classified either as analytic solutions or as numerical solutions using finite difference approach, where the convergence of the numerical schemes depend entirely on the initial and boundary values given.

An extensive literature exist on this subject but until quite recently, group theory has in this respect been unused. In this study, we have used Lie symmetry analysis approach to solve the wave equation given since the solution does not depend on either boundary or initial values and is not an approximation to the exact solution. Thus in our search for the solution we exploited a systematic procedure of developing infinitesimal transformations, generators, prolongations (extended transformations), variational symmetries, adjoint-symmetries, integrating factors and the invariant transformations of the problem. The procedure is aimed at lowering the order of the equation from fourth to first order, which is then solved to provide its Lie symmetry solution. This is the main contribution to the knowledge and further research. (Received September 14, 2014)

1106-VL-1561 **Vladimir Georgiev** and **Daniele Garrisi*** (daniele.garrisi@inha.ac.kr). *Finiteness of positive and radially symmetric standing-wave solutions to a nonlinear Schrödinger equation.* Preliminary report.

The orbital stability of standing-wave solutions to the non-linear Schrödinger equation

$$i\partial_t\varphi + \Delta\varphi + |\varphi|^{p-1}\varphi = 0.$$

has been proved by T. Cazenhave and P. L. Lions in 1983. The proof uses the Concentration-Compactness Theorem of P. L. Lions and relies on the fact that there is only one positive and radially symmetric solution to

$$\Delta u + u^p = \omega u, \quad u \in H^1_r(\mathbb{R}^n), \quad u > 0.$$

for fixed ω. We wish to investigate to what extent such property is preserved when the pure power non-linearity is replaced by a general non-linearity f. We show that, at least when λ is suitably small, there are only finitely many of such solutions. (Received September 14, 2014)

1106-VL-1599 **Agegnehu Atena*** (atenaa@savannahstate.edu), 3219 College St., Savannah, GA 31404. *Numerical Simulation of 3D Thin Metallic Liquid Film Dynamics.*

In the paper by Atena & Khenner, the lubrication-type dynamical model of a molten, pulsed-laser-irradiated metallic film was developed. The heat transfer problem that incorporates the absorbed heat from a single beam or interfering beams is solved analytically. Using this temperature field, the three-dimensional long-wave evolution partial differential equation for the film height was derived. To get insights into dynamics of dewetting, we studied the two dimensional (2D) version of the evolution equation by means of a linear stability analysis and by numerical simulations. In this study we extend our work to study the three-dimensional (3D) version of the evolution of the height of a thin metallic liquid film by numerical simulations. (Received September 14, 2014)

1106-VL-1729 **Guifang Zhou*** (gzhou@math.fsu.edu), 208 Love Building, 1017 Academic Way, Tallahassee, FL 32306, and **Kyle A Gallivan**. *Rank-Constrained Optimization: A Riemannian Manifold Approach.*

Rank-constrained optimization problems have received a lot of attentions recently. Our main interest is providing a new algorithm to solve the optimization problems that involve a rank inequality constraint on a union of Riemannian manifolds. This is in general a non-convex and difficult problem due to the presence of the rank constraint. To deal with this difficulty, we extend the general Riemannian optimization algorithms on the smooth manifold $\mathcal{M}_k$ of rank-k manifold to its closure $\mathcal{M}_{\leq k}$. By taking steps along rank-related directions in the tangent cone, and afterwards using a rank-related retraction to go back to $\mathcal{M}_{\leq k}$, the new algorithm provides an efficient way for the rank updating. Convergence is also proved. Numerical examples demonstrate the basic properties and efficiency of our approach. (Received September 15, 2014)

1106-VL-1885 **Lin Zhao*** (lin.zhao.gr@dartmouth.edu) and **Alex H Barnett** (ahb@math.dartmouth.edu). *Fast and Robust Computation of Laplacian Eigenvalues for Arbitrary Planar Domains.*

The Laplacian spectrum of general multiply-connected planar domains is challenging to obtain with high accuracy. We achieve 12-digit accuracy using the determinant of a combined field integral equation discretized with a Nyström scheme, computed by a fast direct solver at a cost of $O(N \log N)$. On a complicated domain with $N = 3 * 10^4$ boundary nodes, it takes 17 min per eigenvalue found. Joint work with Alex Barnett. (Received September 15, 2014)

1106-VL-1895 **Muhammad Irfan Hameed*** (mhameed@uscupstate.edu), Department of Mathematics, University of South Carolina Upstate, 800 University Way, Spartanburg, SC 29303. *Simplified Mathematical Model of Neck Formation and Breakup of a Slender Fluid Jet.*

The influence of surfactant on the breakup of a periodic fluid jet of low viscosity immersed in highly viscous exterior fluid at low Reynolds number is presented. Evolution equations for the jet interface and surfactant concentration are derived using long wavelength approximations. These one dimensional partial differential equations are solved numerically for given initial interface and surfactant concentration. It is found that the presence of surfactant at the interface retards the pinch-off process. The influence of various physical effects on the breakup process is also investigated. The influence of surface diffusion of surfactant on the thread deformation is studied by varying surface Peclet number. It is found that greater diffusion of surfactant causes the jet to pinch faster. Surfactant solubility is found to have similar effect. Results of the long wavelength model are also compared against the numerical simulations of the full problem. The solution of the full problem shows similar behavior to the simplified model. (Received September 15, 2014)

1106-VL-1912 **Wei Cui*** (wcui@crimson.ua.edu) and **Zhijian Wu** (zhijian.wu@xjtlu.edu.cn).
Fractional Brownian Motion and Hedging with Short-term Futures Contracts. Preliminary report.

Assuming the market model is driving by the fractional Brownian motion (fBm), we study the following optimization problem:
Under the constraint that $F_g(1) \leq x$. Which measurable function $g : [0,1] \to R[0,1]$ will minimize the value $\sup_{t\in[0,1]} F_g(t)$, where $F_g(t) = H(2H-1)\int_0^t \int_0^t \big(t-g(u)\big)\big(t-g(v)\big)|u-v|^{2H-2}dudv$, and $H \in (\frac{1}{2}, 1)$. This problem is related to hedge a long-term supply commitment with short-term futures contracts under a certain constraint on the terminal risk. In this talk, we will show that a unique solution to this problem always exists. (Received September 15, 2014)

1106-VL-1919 **Otis Wright*** (wrighto@cedarville.edu), 251 N. Main St., Cedarville, OH 45314.
Effective integration of ultra-elliptic solutions of the integrable nonlinear Schrödinger equation.

An effective integration method for quasi-periodic ultra-elliptic solutions of the integrable nonlinear Schrödinger equation is studied. The non-zero bounded quasi-periodic two-phase solutions with real quasi-periods are constructed using Kleinian elliptic functions and all real cases are classified. (Received September 15, 2014)

1106-VL-1978 **Ohannes Karakashian** and **Craig D. Collins*** (craig.collins@math.utk.edu).
Two-level Schwarz Methods for Discontinuous Galerkin Approximations of Second Order Elliptic Problems.

We present some two-level non-overlapping and overlapping additive Schwarz methods for solving second order elliptic problems. It is shown that the condition numbers of the preconditioned systems are of the order $O(\frac{H}{h})$ for the non-overlapping Schwarz methods, and of the order $O(\frac{H}{\delta})$ for the overlapping Schwarz methods, where h and H stand for the fine mesh size and the coarse mesh size respectively, and δ denotes the size of the overlaps between subdomains. Numerical experiments are provided to gauge the efficiency of the methods and to validate the theory. (Received September 15, 2014)

1106-VL-2026 **Ilija Jegdic*** (i_jegdic@yahoo.com). *Overlapping grids for hyperbolic conservation laws.*

We consider hyperbolic scalar conservation laws and the problem of numerically computing the solution using two overlapping grids. We develop a method, based on the finite element method, and prove that our numerical approximations converge not only to a weak solution, but to the entropy solution. We present numerical results for the Burgers' equation and the Lax shock-tube problem. (Received September 15, 2014)

1106-VL-2100 **Kyle Golenbiewski*** (kyle@math.utk.edu), **Tim P. Schulze** and **Peter Smereka**.
Analysis of an energy localization method used in Kinetic Monte Carlo simulations of heteroepitaxial growth. Preliminary report.

Heteroepitaxial growth consists of slowly depositing one material onto a crystalline substrate formed from a second material. An important feature of this process is that the natural lattice spacing of the deposited material may differ from that of the substrate's, resulting in elastic strain. Simulation of such growth using Kinetic Monte Carlo is often based on rates determined by differences in elastic energy between two configurations. This, however, is computationally challenging due to the long range nature of elastic interactions. Adopting an atomistic approach, we consider a method in which the elastic field is updated using highly accurate local approximations, though the energies themselves are far less accurate. Namely, we approximate the elastic energy barrier by constraining the displacement field with an atom removed to agree with the displacement field when the atom is present outside some local region. In order to gain insight into this energy localization method, we appeal to a continuum analogue of the discrete mechanical system. For the scenario of an isolated island sitting on an unbounded and otherwise flat film on a flat substrate, we extend earlier results for a 2D system to 3D. (Received September 15, 2014)

1106-VL-2147 **Joseph Richard Sadow*** (jrsadow@asu.edu), P.O. Box 871804, Tempe, AZ 85287. *A split-explicit time-filtered Leapfrog Scheme with Application to Atmospheric Modeling.*

I will describe a novel split-explicit scheme for leapfrog numerical methods. It is based on a 4th order implicit time filter and uses two different time steps: the fast modes are handled implicitly, and the slow modes are calculated using a time-filtered leapfrog method that is implemented as a predictor-corrector scheme. I will give some examples of the ability of the new method to speed up computations, stabilize unphysical modes and will discuss its potential applicability to numerical forecast models. (Received September 15, 2014)

1106-VL-2175 **Alrazi M Abdeljabbar*** (abdeljabbara@savannahstate.edu), 10875 Abercorn St. Apt#712, Savannah, GA 31419. *Applications of the Pfaffain technique to (3+1)-dimensional soliton equations of Jimbo-Miwa type.*

Based on Hirota bilinearization method, the Pfaffain technique is employed to construct an explicit exact solutions to 3+1-dimensional nonlinear partial differential equations of Jimbo-Miwa type. Pfaffainization procedure will also be applied to extend such equations to a new coupled systems. (Received September 16, 2014)

1106-VL-2184 **Shane Michael Lubold*** (shane@lubold.com), 130 E. 14th Street, Tempe, AZ 85281, and **Anne Gelb**. *Higher-Order Concentration Factor Design For Nonlinear Underlying Functions in Fourier Edge Detection.*

The detection and characterization of changes or edges in signals is important in a number of signal-processing applications. Many of these applications collect data in the Fourier domain, which makes edge detection difficult because Fourier data are global, while edges are local features. The concentration factor method uses a first order accurate relationship between Fourier coefficients and the edges of the corresponding unknown function to devise a family of band pass filter (the concentration factors) that generates an approximation concentrating at the singular support of the underlying function, thereby detecting its edges.

In recent results, concentration factors were reverse-engineered based on this first order relationship between the Fourier coefficients and its corresponding edges. Specifically, concentration factors were constructed to find the edges of a saw tooth function. It is clear that for applications in which the underlying function has more variation between the edges, the concentration factor method may not be effective. Hence we develop new concentration factors that allow for more variation between the edges. The covariance of the different concentration factors enables us to predict edges in piecewise analytic functions with multiple jumps. (Received September 16, 2014)

1106-VL-2265 **Jessica D. Stewart*** (jessica.stewart@goucher.edu), 1021 Dulaney Valley Road, Baltimore, MD 21204. *A Third Type of Exceptional Laguerre Polynomials.* Preliminary report.

In 2009, Gómez-Ullate, Kamran, and Milson extended the well-established Bochner Classification (1929) by showing that the only polynomial sequences $\{p_n\}_{n=1}^{\infty}$ which simultaneously form a complete set of eigenstates for a second-order differential operator and are orthogonal with respect to a positive Borel measure having positive moments are the exceptional X_1-Laguerre and X_1-Jacobi polynomials. Since then, the result has been further extended to study other exceptional orthogonal polynomials $\{p_n\}_{n\in\mathbb{N}_0\setminus A}$ where A is a finite subset of $\mathbb{N}_0$ and where $\deg p_n = n$ for all $n \in \mathbb{N}_0\setminus A$. Sequences of this nature are referred to as exceptional X_m sequences, where $m = |A|$. Remarkably, even in this more general setting, the sequences remain complete in their corresponding Hilbert space setting. There are two established types of exceptional X_m-Laguerre polynomial sequences. Here we will address a third type of X_m-Laguerre sequence. In particular, we will discuss the relationship of this new Type III sequence to the Type I exceptional X_m-Laguerre polynomials, along with orthogonality, norms, local extrema, and location of roots. (Received September 16, 2014)

1106-VL-2275 **Thomas G Stojsavljevic*** (tom.stojsavljevic@gmail.com), 1428 E Capitol Drive, Apartment 1, Shorewood, WI 53211. *Mathematical Modeling of Competition for Light and Nutrients Between Phytoplankton Species in a Poorly Mixed Water Column.*

Phytoplankton live in a complex environment with two essential resources forming various gradients. Light supplied from above is never homogeneously distributed in a body of water due to refraction and absorption from biomass present in the ecosystem and from other sources. Nutrients in turn are typically supplied from below. In poorly mixed water columns phytoplankton can be heterogeneously distributed forming various layering patterns. The relationship between the location and the thickness of the layers is an open problem of interest. Here we present three models which study how competition for light and resources can form common layering patterns seen in nature and investigate how the location and thickness of the layer changes when the motility of the phytoplankton is varied. Using this we study the phenomenon of coexistence of multiple phytoplankton species and the presence of species spatial separation. (Received September 16, 2014)

1106-VL-2295 **Chang Hyeong Lee** and **Xingye Kan*** (xkan@umn.edu), 204 Vincent Hall, 206 Church St SE, Minneapolis, MN 55455, and **Hans G. Othmer**. *A Multi-Time-Scale Analysis of Chemical Reaction Networks in Stochastic Description.*

We consider stochastic descriptions of reaction networks in which there are both fast and slow reactions, and the time scales are widely separated. We obtain a reduced equation on a slow time scale by applying a state space decomposition method to the full governing equation and describe our reduction method on the reaction simplex. Based on the analytic results, we approximate reaction probabilities, or so-called propensity functions and present an efficient stochastic simulation algorithm for the slow time scale dynamics. We illustrate the numerical accuracy of the approximation by simulating several motivating examples. (Received September 16, 2014)

1106-VL-2352 **Farrah Sadre-Marandi*** (sadre@math.colostate.edu), Department of Mathematics, 1874 Campus Delivery, Fort Collins, CO 80523-1874. *A Matlab Toolbox for Darcy Flow Computations.*

This talk presents a compact Matlab toolbox for solving the Darcy equation in modeling flow in porous media. The toolbox includes the newly developed weak Galerkin finite element methods (WGFEMs), the classical mixed finite element methods (MFEMs), and the discontinuous Galerkin finite element methods (DGFEMs). We demonstrate that WGFEMs are viable alternatives of MFEMs for Darcy flow computations. GUI design in the toolbox will be discussed also. (Received September 16, 2014)

1106-VL-2416 **Richard Schugart***, Department of Mathematics, 1906 College Heights Blvd. #11078, Bowling Green, KY 42101-1078, **Stephen Guffey**, Department of Mathematics, 1906 College Heights Blvd. #11078, Bowling Green, KY 42101-1078, and **K Renee Fister**. *Using Optimal Control Theory with a PDE Model for the Treatment of a Bacterial Infection in a Wound Using Oxygen Therapy.*

An optimal control problem has been formulated for the treatment of a bacterial infection in a wound using oxygen therapy using partial differential equations. The optimality system and existence of the weak state solution will be presented in this talk. Existence of the optimal control and adjoint system will be discussed. (Received September 16, 2014)

1106-VL-2464 **Geena Ildefonso*** (geena.ildefonso@ucf.edu), 4750 Fiske Circle, Orlando, FL 32826. *Cancer Lineages and Radiotherapy.* Preliminary report.

In recent years, studies have shown that only small subpopulations of tumor cells are responsible for the relentless growth of tumors. These cells are known as cancer stem cells (CSC). Here, we propose to investigate the use of radiotherapy in cancer treatment of heterogeneous tumors containing stem and non-stem cells. A featured approach is the incorporation of feedback processes regulating cell behavior. We develop a mathematical model of the cell dynamics using differential equations and the linear-quadratic model to estimate the survival of cells to radiation exposure. To simulate spatial effects, we also plan to use the Cellular-Potts model in which individual cells are represented as a collection of pixels and the dynamics are governed through an algorithm that is based on an energy that also takes into account adhesion, motility, and cell stiffness. To parameterize the models, we will use data from brain tumors provided by the laboratory of F. Pajonk (UCLA). The goal is to develop tumor-specific therapy schedules and dosages to optimize response of tumors to radiation treatment. This is an important step towards developing individualized therapy protocols where therapy is designed to optimize response for patient-specific tumor cells. (Received September 16, 2014)

1106-VL-2488 **Hy Dinh*** (hdinh885@g.rwu.edu), Warren, RI , and **Yajni Warnapala**. *The Numerical Solution of the Exterior Impedance (Robin) Problem for the Helmholtz's Equation via Modified Galerkin Method: Super Ellipsoid.*

The Helmholtz Equation, also known as the wave equation, emerges when the topic of electromagnetism and radiation are discussed. It consists of a combination of partial differential equations that investigates how a previously defined object reacts towards incoming waves from all directions. In reality, most surrounding objects are exposed to various types of waves. However, the reactions are neglected for being insignificant and also not observable by the naked eye. I focused on the acoustic aspects of the Helmholtz Equation when the object is submerged underwater or outer space. The surface should be smooth and simply connected. I applied the Green's Functions approach by reducing the problem to a boundary value problem by disregarding what happens in the interior of the desired object and only looking at its membrane. In previous papers, the Neumann and Dirichlet conditions were analyzed. However, for they only study the two extremes of reflecting (Neumann) and absorbing (Dirichlet) the waves that come in contact with the surface, I investigated the more realistic condition that combines the previous two conditions, the Impedance (Robin) condition. (Received September 16, 2014)

1106-VL-2496 **Walid Sharabati*** (wsharaba@purdue.edu), 250 N University St, Department of Statistics, West Lafayette, IN 47907, and **Yanling Zhao**. *De-noising and Deblurring Images Based on Tichonov Regularization With Random Data.*

In this work, we present a stochastic model to the inverse problem in image analysis based on Tikhonov regularization with random input data to reconstruct the original image and reduce noise. We assume the noise induced on the image is Gaussian or white noise. The optimizer produces a nonlinear system of equations. We introduce a stochastic smoothing or blurring operator acting on the image, and another random Tikhonov parameter. The stochastic model reduces the mean square error of the denoised and deblurred image by about 20% on average compare to the deterministic model. (Received September 16, 2014)

1106-VL-2583 **Stanley R Huddy*** (huddys@newpaltz.edu), SUNY New Paltz Department of Mathematics, Faculty Office Building, 1 Hawk Dr., New Paltz, NY 12561, and **Joseph D Skufca**. *Complete Synchronization on Networks of Identical Oscillators with Diffusive Delay-Coupling.*

We examine networks of identical oscillators with diffusive delay-coupling and a single, constant delay tau, and identify necessary conditions for complete complete synchronization. We show that complete synchronization is possible only when at least one of the following conditions is met: (1) all nodes have the same in-degree, (2) the node dynamics (the uncoupled system) have a tau-periodic solution, and synchronized system solution is simply that periodic solution, or (3) the synchronized solution is a fixed point. Numerical simulations of three five-node networks are presented as examples of synchronization on such networks. (Received September 16, 2014)

1106-VL-2587 **'Kale Oyedeji*** (kale.oyedeji@morehouse.edu), Dept of Physics, Morehouse College, Atlanta, GA 30314-3773, and **Ronald E. Mickens**. *Numerical Determination of the Fourier Coefficients for the Leah-Cosine Function.*

The Leah-cosine function, $Lcn(t)$, is the solution to the initial-value problem

$$\frac{d^2x}{dt^2} + x^{\frac{1}{3}} = 0, \qquad x(0) = 1, \quad \frac{dx(0)}{dt} = 0. \qquad ()$$

This nonlinear ODE has the first-intergral

$$y^2 + \frac{3}{2}x^{\frac{4}{3}} = \frac{3}{2}, \qquad y = \frac{dx}{dt}, \qquad ()$$

and from it we can reach the following conclusions:

(a) All solutions are periodic.

(b) The exact value of the period, T, can be calculated and is expressible in terms of gamma functions.

(c) The Leah-cosine function has the same general properties as those exhibited by the standard trigonometric cosine function.

(d) $Lcn(t)$ has the Fourier representation

$$Lcn(t) = \sum_{k=0}^{\infty} a_k \cos(2k+1)\left(\frac{2\pi}{T}\right)t$$

In this presentation, we present our numerical estimates for the Fourier coefficients, (a_k), and derive many of the features stated above. (Received September 16, 2014)

1106-VL-2645 **Michael A Mikucki*** (mikucki@math.colostate.edu). *Modeling protein mediated changes in membrane morphology.*

Lipid bilayer membranes are ubiquitous in biology. They serve as boundaries of cells and cell organelles and undergo large deformations while acting as smart controls for the transport of ions, amino acids, and other nutrients. Simulating membrane deformations from protein-membrane interactions is important toward understanding cellular processes. In this presentation, we give a continuum elasticity description for the membrane and model the deformations in three separate projects. First, a fast algorithm for deformations under the membrane's own mechanical energy is presented with numerical results. Second, an energy functional is defined and justified for the electrostatic interactions between a charged lipid membrane and a nearby protein. We also provide a method to implement the energy functional to the fast algorithm. Finally, a diffuse interface method for modeling multicomponent vesicles is discussed. In particular, we consider a membrane composed of multiple lipid species and more importantly, membrane bound proteins, in efforts to model vesicle budding and scission. (Received September 16, 2014)

1106-VL-2652 **Pablo U Suarez*** (psuarez@desu.edu), Delaware State University, 1200 N Dupont Hwy, Dover, DE 19901. *On the Fokker-Planck equation for a coupled system of van-der Pol Oscillators.* Preliminary report.

This work is motivated by applications to laser dynamics and, more generally, to microwave oscillators. We discuss the Fokker-Planck equation that comes from a coupled system of van-der Pol Oscillators in the presence of multiplicative and additive gaussian white noise. The steady state probability density function is obtained and some numerical results are presented for the transient probability density function. (Received September 16, 2014)

1106-VL-2775 **Csilla Szabo*** (cszabo@bard.edu). *Network Model for Water and Energy Infrastructure.*

Water and energy sustainability continues to be a challenge faced across the world. With continued urbanization and changes in the Earth's climate, these challenges will likely multiply in the decades to come. The resource networks of energy and water are directly linked and vital to the success of a country. The complexity of this network is a challenge for governments of developing nations. Here we model the existing flow networks of water and energy as a multi-layered network. We analyze the synchronization of this network to build a more resilient and robust infrastructure. (Received September 16, 2014)

1106-VL-2792 **Abhinandan Chowdhury*** (achowdhu@gettysburg.edu), Gettysburg, PA 17325, and **Mark L Delcambre**. *A numerical study of the potential flow around two spheres in arbitrary motion through an ideal fluid.* Preliminary report.

The velocity potential of an ideal fluid around two spheres having constant velocity is considered. Bi-spherical coordinates are used, together with a transformation of the dependent variable that leads to separation of variables. Then the solution can be sought in Legendre series with respect to one of the bi-spherical coordinates. An important element of the proposed work is the effective way to reduce an essentially 3D problem to a set of three 2D problems. The Legendre spectral method is shown to have an exponential convergence which is confirmed by the computations. The efficiency is so high that even for the hard cases of two closely situated spheres, an accuracy of 10^{-15} is achieved with as few as 20 terms in the expansion. (Received September 16, 2014)

1106-VL-2881 **Duane Chin-Quee*** (dchinque@irsc.edu), 3209 Virginia Ave., Ft Pierce, FL 34981. *Functional Differential Equations with Linear Anticipation and Retardation Operators.*

We consider functional differential equations (FDEs) involving linear anticipation and retardation operators.The operators satisfy the mapping $C(\mathbb{R},\mathbb{E}) \to B(\mathbb{R},\mathbb{E})$ where $\mathbb{E}$ is a Banach Space and B is the linear space of all measurable functions $f : \mathbb{R} \to \mathbb{E}$ that are Bochner-Integrable on each compact interval. Existence and uniqueness results with prescribed boundary conditions will be presented along with applications. (Received September 17, 2014)

1106-VL-2914 **Javier Garza*** (garza@tarleton.edu), Stephenville, TX 76402. *Optimal Control of Mastitis in Dairy Cow Populations.*

Mastitis is a pathogenic disease, the transmission of which in dairy cow herds costs the U. S. dairy industry nearly $2 billion annually. A model describing the transmission dynamics of environmental and contagious mastitis within a dairy cow population is presented. Sensitivity analysis and optimal control theory are utilized to analyze treatment and prevention protocols. (Received September 17, 2014)

1106-VL-2925 **Josef A Sifuentes*** (josefs@math.tamu.edu), **Leslie Greengard** and **Zydrunas Gimbutas**. *Randomized methods for rank-deficient linear systems.*

We present a simple, accurate method for solving consistent, rank-deficient linear systems, with or without additional rank-completing constraints. Such problems arise in a variety of applications, such as the computation of the eigenvectors of a matrix corresponding to a known eigenvalue. The method is based on elementary linear algebra combined with the observation that if the matrix is rank-k deficient, then a random rank-k perturbation yields a nonsingular matrix with probability close to 1. (Received September 17, 2014)

General Session on Research in Geometry

1106-VM-308 **Casey L Kelleher*** (clkelleh@uci.edu), UCI Mathematics Department, 340 Rowland Hall (Bldg.# 400), University of California, Irvine, CA 92697-3875, and **Jeffrey D Streets**. *Entropies, Stability and Yang-Mills Flow.* Preliminary report.

Following Colding and Minicozzi's *Generic mean curvature flow I; generic singularities*, we define a notion of entropy for connections over $\mathbb{R}^n$ which has shrinking Yang-Mills solitons as critical points. We compute the second variation of this entropy, which leads to a natural definition of stability for a shrinking soliton. As a consequence this discussion leads to a gap theorem for shrinkers. These results point to a broader strategy of studying "generic singularities" of Yang-Mills flow, and we discuss the differences in this strategy in dimension $n = 4$ versus $n \geq 5$. We conclude with some discussion of open problems. (Received August 20, 2014)

1106-VM-366 **Ronan J Conlon***, rconlon@cirget.ca, and **Hans-Joachim Hein**. *An affine Calabi-Yau manifold with irregular tangent cone at infinity.*

An asymptotically conical (AC) Calabi-Yau manifold is a non-compact Ricci-flat Kahler manifold modelled on a Ricci-flat Kahler cone at infinity. I will present a new example of an AC Calabi-Yau manifold with asymptotic model an irregular Ricci-flat Kahler cone. This example in particular provides the first example of an affine Ricci-flat Kahler manifold of Euclidean volume growth with irregular tangent cone at infinity. This is joint work with Hans-Joachim Hein (UMD). (Received August 25, 2014)

1106-VM-1116 **Anthony J. Macula*** (macula@geneseo.edu), Mathematics Department, SUNY Geneseo, Geneseo, NY 14454. *On the maximum and minimum number of "sets" in subspaces of the affine space represented by the cards in the game of SET.*

The card game SET is a representation of the four dimensional affine space over the finite field of order three. In this talk, variations of the following question will be explored: Given a positive integer k, what is the maximum (minimum) number of lines (i.e., "sets" in the game) that can be contained in a subset of k cards taken from the deck? A simple formula connecting the maximum and minimum values will be derived and applied. (Received September 10, 2014)

1106-VM-1251 **Ryan Hood** and **J Mealy*** (jmealy@austincollege.edu), Austin College, suite 61560, 900 North Grand Avenue, Sherman, TX 75090. *Spiraling geodesics in staircase metric geometries.*

Further results in the category, staircase metric geometry. First, a brief introduction to this new category of geometric systems is given, primarily by illustrating the construction of varied complete geodesics in specific staircase metric geometries. While new, these geodesics are not dissimilar from their familiar classical counterparts in models of the 2-dimensional hyperbolic plane. However, we then undertake constructions of geodesics that have less familiar properties. Specifically, we construct SMG systems that feature spiraling geodesics, and investigate further the properties of these objects. While our construction scheme is 'richer' in the flat parameter space case, we establish the existence of such a geodesic in one spherical parameter space case as well. Finally, further directions in the work are outlined. (Received September 12, 2014)

1106-VM-1472 **Philip DeOrsey*** (philip.deorsey@ucdenver.edu) and **William Cherowitzo** (william.cherowitzo@ucdenver.edu). *Cyclotomic Sets in AG(2, q).*

We let AG$(2, q)$ denote the affine plane coordinatized by the finite field with q elements, GF(q). As is well known, the points of AG$(2, q)$ can be represented as elements of GF(q^2). A *cyclotomic set* is an orbit of elements of GF(q^2) under a field automorphism and is thought of as a geometric structure in AG$(2, q)$. We will discuss the structures known to be represented by cyclotomic sets, one of which is a cyclic n_3 configuration. An n_3 configuration is a point-line incidence structure containing n points and n lines, with 3 lines through every point, and 3 points on every line. A configuration is cyclic if there is an automorphism of the configuration that permutes the points in a full cycle. In this talk we determine all generating blocks for cyclic n_3 configurations, which allows us to describe when a cyclotomic set contains a cyclic n_3 configuration. (Received September 13, 2014)

1106-VM-1578 **Derege H Mussa*** (derege.mussa@utdallas.edu), 800 West Campbell Road, Richardson, TX 75080, Dallas, TX 75080. *Degenerate Tetrahedra.* Preliminary report.

Three dimensional will give an enormous amount of attentions to graphical representation and mental visualization. A tetrahedron (plural tetrahedra) is the simplest three dimensional solid having four vertices, four triangular faces and six edges which don't lie in a single plane. A partition of a positive integer n is a way of writing n as a sum of positive integers and is denoted by the list of positive integers in the sum. Partitions of

6,namely6,,5, 1,4, 2, 4, 1, 1,3, 3,3, 2, 1,3, 1, 1,1,2, 2, 2,2, 2, 1, 1, 2, 1,1,1,1,1, 1, 1, 1, 1, 1. The number of edges of tetrahedron offers a way to classify tetrahedra, and to address questions of research interest to mathematicians, while offering k-12 students a laboratory to make models, and get insight into representation of geometrical objects, visualizing these objects,and telling when the objects are the same or different.A sextuple S = (a, b, c, d, e, f) is a degenerate tetrahedron if and only if S is facial (the lengths of the edges of each four face must obey the (strict) triangle inequality) and that the McCrean determinant is zero.The paper discuss the degenerate tetrahedral,When does a degenerate tetrahedron with specific edge lengths exist? How can we classify degenerate tetrahedra in a natural way? (Received September 14, 2014)

1106-VM-1621 **Timo de Wolff*** (dewolff@math.tamu.edu) and **Sadik Iliman**. *Amoebas, Nonnegative Polynomials and Sums of Squares Supported on Circuits.*

We completely charaterize sections of the cones of nonnegative polynomials and sums of squares with *polynomials supported on circuits* – a genuine class of sparse polynomials. In particular, nonnegativity is characterized by an invariant, which can be immediately derived from the initial polynomial via using a new norm based relaxation strategy. Based on these results, we obtain a completely new class of nonnegativity certificates independent from sums of squares certificates.

Furthermore, nonnegativity of such polynomials f coincides with solidness of the *amoeba* of f, i.e., the Log-absolute-value image of the algebraic variety $V(f) \subset (\mathbb{C}^*)^n$ of f.

These results establish a first direct connection between amoeba theory and nonnegativity of polynomials. They generalize earlier works both in amoeba theory and real algebraic geometry by Fidalgo, Kovacec, Reznick, Theobald and de Wolff. (Received September 14, 2014)

1106-VM-1647 **Yoav Len*** (yoav.len@yale.edu), Yale University, 10 Hillhouse Ave., 442 Dunham Lab, New Haven, CT 06511. *Tropical Brill-Noether theory.*

I will discuss various results relating algebraic and combinatorial aspects of line bundles on curves. In tropical geometry, we associate a graph to an algebraic curve via a process known as *tropicalization*. Using lifting theorems, statements about the geometry of curves can be reformulated in terms of combinatorial problems on graphs. In my talk, I will introduce the theory of divisors on graphs, and explain how it can be applied to the study of line bundles on curves via degeneration. (Received September 14, 2014)

1106-VM-1851 **Jacob M Blackwood** and **Adam M Dukehart*** (am06duke@siena.edu), Siena College, 515 Loudon Road, Loudonville, NY 12211. *Loxodromic Curves on Surfaces of Revolution.*

A loxodrome is a spherical curve that makes a constant angle with the meridians. We investigate loxodromic curves on surfaces of revolution and show that the differential equation arising from the constant angle constraint is a separable equation. In addition, we discuss loxodromic curves in higher dimensions by using the notion of parallel transport in Differential Geometry. (Received September 15, 2014)

1106-VM-1872 **Nurten (Bayrak) Gürses*** (nbayrak@yildiz.edu.tr), Yıldız Technical University, Faculty of Arts and Sciences, Department of Mathematics, 34220 Istanbul, Turkey, and **Salim Yüce**. *On the Moving Coordinate System and Pole Points in Affine Cayley-Klein Planes.*

In 1956, W. Blaschke and H.R. Müller introduced the one-parameter planar motions and obtained the relation between absolute, relative, sliding velocities and accelerations in the Euclidean plane $\mathbb{E}^2$. A. A. Ergin, considering Lorentzian plane $\mathbb{L}^2$ instead of the Euclidean plane $\mathbb{E}^2$, introduced the one-parameter planar motions and also gave the relations between the velocities and accelerations in 1991. Also, in 2013, M. Akar and S. Yüce introduced the one-parameter motions in the Galilean plane $\mathbb{G}^2$. Then, N. (Bayrak) Gürses and S. Yüce give the one-parameter motions in affine Cayley-Klein planes $\mathbb{P}_\epsilon$ in 2014. In this present paper, we will take into consideration three affine Cayley-Klein planes: A_ϵ and $\mathbb{P}_\epsilon$ and $\mathbb{P}'_\epsilon$. $\mathbb{P}'_\epsilon$ is a fixed plane relative to two other moving affine Cayley-Klein planes. We will discussed the relation between the motions $A_\epsilon/\mathbb{P}_\epsilon$, $A_\epsilon/\mathbb{P}'_\epsilon$ and $\mathbb{P}_\epsilon/\mathbb{P}'_\epsilon$ with evaluating their derivative formulae, velocity vectors and pole points. (Received September 15, 2014)

1106-VM-1900 **Milé Krajcevski*** (mile@mail.usf.edu), University of South Florida, Department of Mathematics & Statistics, 4202 East Fowler Av., CMC342, Tampa, FL 33620-5700. *Do typical visual representations obstruct mathematical cognition?* Preliminary report.

In this talk we reflect on the powerful role typical visual representations of some mathematical notions in geometry play in students' ability to formulate mathematical arguments. We notice that some of the difficulties associated with the use of visualization as a facilitator of mathematical cognition, are results of our inability to escape these typical representations. We report on a pilot study conducted on a small scale among prospective middle school mathematics teachers. (Received September 15, 2014)

1106-VM-2204 **Gülsüm Yeliz Şentürk*** (ysacli@yildiz.edu.tr), Yıldız Technical University, Faculty of Arts and Sciences, Department of Mathematics, 34220 Istanbul, Turkey, and **Salim Yüce**. *Properties of Integral Invariants of The Ruled Surface with Darboux Frame in* $\mathbb{E}^3$.

In this study, the ruled surface with Darboux frame in $\mathbb{E}^3$ is taken into consideration. Some theorems about the pitch and the angle of the pitch which are the integral invariants of the surface are given and some special cases of the rulings are demonstrated according to $\{\mathbf{T}, \mathbf{N}, \mathbf{B}\}$ Frenet frame with $\{\mathbf{T}, \mathbf{g}, \mathbf{n}\}$ Darboux frame. (Received September 16, 2014)

1106-VM-2205 **Özcan Bektaş*** (obektas@yildiz.edu.tr), Yıldız Technical University, Faculty of Arts and Sciences, Department of Mathematics, 34220 ISTANBUL, Turkey, and **Salim Yüce** (sayuce@yildiz.edu.tr), Yıldız Technical University, Faculty of Arts and Sciences, Department of Mathematics, 34220 ISTANBUL, Turkey. *On The Octonionic Inclined Curves In The 8 Dimensional Euclidean Space.*

In this study, we describe octonionic inclined curves and harmonic curvatures for the octonionic curves. We give a characterizations for an octonionic curve to be an octonionic inclined curve. And finally, we obtain some characterisations for the octonionic inclined curves in terms of the harmonic curvatures. (Received September 16, 2014)

1106-VM-2243 **Jonathan E Holland*** (jonathan.e.holland@gmail.com), 356 S Graham St, Apt 4, Pittsburgh, PA 15232. *Cosmologies determined by pairs of quadrics.*

We present a family of conformally flat cosmological spacetimes that arise naturally by breaking of symmetry from the full conformal spin group $SU(2, 2)$. These spacetimes are determined by a pair of quadrics in a three dimensional complex projective space, the twistor space, and using a construction going back to Battaglini are connected with the classical algebraic geometry of quadric line complexes. (Received September 16, 2014)

1106-VM-2269 **Faruk F. Abi-Khuzam*** (farukakh@aub.edu.lb), Beirut, Lebanon. *Geometry of the Fermat-Torricelli problem.*

Given a triangle A and weights m_1, m_2, m_3, a geometric proof is given of (a) the existence of a point F whose weighted distance sum $m_1|F - A_1| + m_2|F - A_2| + m_3|F - A_3|$ has the smallest possible value, (b) the value of this minimum, and (c) the construction of the point. A characterization of the weights that guarantees the point is inside the triangle is given.This is then used to supply solutions to three extremal problems, as well as to generate sharp inequalities connecting the elements of triangle $A_1A_2A_3$. (Received September 16, 2014)

1106-VM-2324 **Salim Yüce*** (sayuce@yildiz.edu.tr), Yıldız Technical University, Faculty of Arts and Sciences, Department of Mathematics, 34220 ISTANBUL, Turkey, and **Özcan Bektaş** (obektas@yildiz.edu.tr), Yıldız Technical University, Faculty of Arts and Sciences, Department of Mathematics, 34220 ISTANBUL, Turkey. *On The Special Octonionic Curves In The 8 Dimensional Euclidean Space.*

In this study, we describe special octonionic curves. We give characterizations for an octonionic curve to be special octonionic curve. And finally, we obtain some characterisations for the special octonionic curves. (Received September 16, 2014)

1106-VM-2678 **Dat P Nguyen*** (datnguyenp@gmail.com). *A simple proof of Bernstein theorem for de Sitter spaces.*

The classical Bernstein problem in differential geometry asks whether every complete hypersurface in Euclidean spaces that extremizes volume is a hyperplane. The answer is positive for dimensions less than 8 and negative for higher dimensions. However, in the setting of spacetime geometry, the result is drastically different. The Bernstein theorem for Minkowski spacetimes was proven in all dimensions by Calabi (1970) and Cheng-Yau (1976). Later, Nishikawa (1984) extended the result to all locally symmetric Lorentzian manifolds that satisfy some energy conditions. In this talk, we give a simple proof of Bernstein theorem for de Sitter spaces, which are the Lorentzian analogues of the round n-spheres. This work was done under the supervision of Professor Claude LeBrun. (Received September 16, 2014)

1106-VM-2712 **Joseph P Previte*** (jpp4@psu.edu), 4701 College Drive, Erie, PA 16563, and **Michelle Previte** (mlp17@psu.edu), 4701 College Drive, Erie, PA 16563. *Triangles in Wonderland. Are there more obtuse or acute triangles?*

We will present Charles Dodgson's (a.k.a. Lewis Carroll of Alice in Wonderland fame) formulation of this problem together with his proof in the plane. This will be followed by the generalization to n dimensions. (Received September 16, 2014)

1106-VM-2743 **Ehssan Khanmohammadi*** (khanmoha@math.psu.edu). *On the Positivity of Kirillov's Character Formula.*

I will review the Kirillov-Kostant philosophy of coadjoint orbits and then discuss the positivity property of Kirillov's character formula for some classes of Lie groups. Finally, I will explain how this positivity property can be used to construct a group representation from an orbit of the coadjoint representation. (Received September 16, 2014)

1106-VM-2859 **Adrian Brunyate*** (brunyate@math.uga.edu), Dept. of Mathematics, University of Georgia, Athens, GA 30602. *A Compact Moduli Space of Elliptic K3 Surfaces.* Preliminary report.

We will discuss recent results detailing a geometric (KSBA-type) compactification of the moduli of elliptic K3 surfaces,including how to explicitly compute limits and how the compactification relates to toroidal compactifications of the period domain. (Received September 16, 2014)

General Session on Research in Graph Theory

1106-VN-78 **H. Kierstead**, **A. Kostochka**, **T. Molla** and **E. Yeager*** (yeager2@illinois.edu). *Disjoint Cycles and Equitable Coloring.*

In 1963, Corrádi and Hajnal famously proved the following: If a graph has minimum degree at least $2k$, and at least $3k$ vertices, then it contains a set of k vertex-disjoint cycles. The degree bound is sharp, but has been improved by considering Ore-type conditions. That is, by bounding the minimum degree sum of nonadjacent vertices, instead of bounding the minimum degree.

An *equitable coloring* of a graph is a proper vertex coloring where no two color classes differ in size by more than one. The most obvious relation between equitable coloring and the problem of finding disjoint cycles is this: A graph G on $3k$ vertices contains a set of k disjoint cycles if and only if the complement of G is equitably k-colorable. Chen, Lih, and Wu conjectured in 1994 that a connected graph G is $\Delta(G)$-equitably colorable if it is different from K_m, C_{2m+1}, and $K_{2m+1,2m+1}$ for every $m \geq 1$. We discuss an Ore-type analog to this conjecture: that every k-colorable graph G with maximum degree sum of adjacent vertices at most $2k+1$ is equitably k-colorable unless it contains $K_{1,2k} + K_{k-1}$; $K_{c,2k-c} + K_k$ for odd c; or a third graph in the case $k = 3$. (Received July 03, 2014)

1106-VN-215 **Natasha Komarov*** (nkom@cmu.edu) and **John Mackey**. *Containment: A Variation of Cops and Robbers.*

We consider "Containment": a variation of the graph pursuit game of Cops and Robber in which cops move from edge to adjacent edge, the robber moves from vertex to adjacent vertex (but cannot move along an edge occupied by a cop), and the cops win by "containing" the robber—that is, by occupying all $\deg(v)$ of the edges incident with a vertex v while the robber is at v. We develop bounds that relate the minimal number of cops, $\xi(G)$, required to contain a robber to the well-known "cop-number" $c(G)$ in the original game: in particular, $c(G) \leq \xi(G) \leq \gamma(G)\Delta(G)$. We note that $\xi(G) \geq \delta(G)$ for all graphs G, and analyze several families of graphs in which equality holds, as well as several in which the inequality is strict. We also give examples of graphs which require an unbounded number of cops in order to contain a robber, and note that there exist cubic graphs with $\xi(G) \geq \Omega(n^{1/6})$. (Received August 11, 2014)

1106-VN-228 **Kavish P Gandhi*** (kmbrgandhi@gmail.com) and **Chiheon Kim**. *Saturation of Trees in the Hypercube.* Preliminary report.

Within the hypercube Q_n, we investigate bounds on the *saturation number* of a forbidden graph G, defined as the minimum number of edges in a maximal G-free subgraph H of Q_n. For all graphs G, we find a lower bound on the saturation number based on the minimum degree of non-leaves. For upper bounds, we first examine general graphs and derive conditions that, if satisfied, allow us to bound the saturation number. We also study specific cases, finding improved bounds for paths, generalized stars, most caterpillars, and certain other classes of trees. In all of these cases, we find bounds that are $O(2^n)$ with either a linear or constant multiplier, an interesting fact that we conjecture to hold for all trees. (Received September 10, 2014)

1106-VN-242 **Nathaniel Karst**, **Jessica Oehrlein*** (jessica.oehrlein@students.olin.edu), **Denise Sakai Troxell** and **Junjie Zhu**. *Distance Labelings of Amalgamations and Injective Labelings of General Graphs.*

An $L(2,1)$-labeling of a graph G is a function assigning a non-negative integer to each vertex such that adjacent vertices are labeled with integers differing by at least 2 and vertices at distance two are labeled with integers differing by at least 1. The minimum span across all $L(2,1)$-labelings of G is denoted $\lambda(G)$. An $L'(2,1)$-labeling of G and the number $\lambda'(G)$ are defined analogously, with the additional restriction that the labelings must be injective. We determine $\lambda(H)$ where H is a join-page amalgamation of graphs which is defined as follows: given $p \geq 2$, H is obtained from the pairwise disjoint union of graphs $H_0, H_1, \cdots, H_p$ by adding all the edges between a vertex in H_0 and a vertex in H_i for $i = 1, 2, \cdots, p$. Motivated by these join-page amalgamations, we show that $\lambda'(G) = \max\{n-1, \lambda(G)\}$, where n is the number of vertices in G. (Received August 13, 2014)

1106-VN-294 **Adam Volk*** (volka1@udayton.edu) and **Joshua Mireles**. *Gridline Graphs in Higher Dimensions.* Preliminary report.

A gridline graph is a graph G whose vertices can be realized in $\mathbb{R}^2$ in such a way that the vertices are adjacent if and only if they lie on a vertical or horizontal line, in other words they share a coordinate. These graphs can be characterized as line graphs of bipartite graphs and as diamond, claw, and odd-hole free graphs. We generalize gridline graphs to n dimensions by letting vertices be adjacent whenever they line on the same hyperplane, that is they share *at least one* coordinate. We investigate how characterizations of the 2-dimensional gridline graphs generalize to n dimensions and provide more specific results for the case where $n = 3$. This research was conducted as part of the 2014 REU program at Grand Valley State University. (Received August 19, 2014)

1106-VN-520 **Matthew J Prudente*** (mjp209@lehigh.edu), 8 Duh Dr, Apt 221, Bethlehem, PA 18015. *Two-Player Pebbling on Diameter 2 Graphs.* Preliminary report.

Given a graph G with pebbles on the vertices, we define a *pebbling move* as removing two pebbles from a vertex u, placing one pebble on its neighbor v and discarding the other pebble as a toll. The *pebbling number* $\pi(G)$ is the least number of pebbles needed so that every arrangement of $\pi(G)$ pebbles can place a pebble on every goal vertex r through a sequence of pebbling moves. We introduce a new variation on graph pebbling called *two-player pebbling*. In this, players called the *mover* and the *defender* alternate moves, with the stipulation that the defender cannot reverse the previous move. The mover wins if they can place a pebble on the root and the defender wins if the mover cannot. We define $\eta(G)$, analogously, as the minimum number of pebbles such that given every configuration of the $\eta(G)$ pebbles and every root vertex r, the mover has a winning strategy. We investigate winning strategies and configurations for both players on a special class of diameter 2 graphs (Received September 01, 2014)

1106-VN-573 **A. V. Kostochka** and **B. M. Reiniger*** (reinige1@illinois.edu). *The minimum number of edges in a 4-critical graph that is bipartite plus 3 edges.*

Rödl and Tuza proved that sufficiently large $(k+1)$-critical graphs cannot be made bipartite by deleting fewer than $\binom{k}{2}$ edges, and that this is sharp. Chen, Erdős, Gyárfás, and Schelp constructed infinitely many 4-critical graphs obtained from bipartite graphs by adding a matching of size 3 (and called them $(B+3)$-graphs). They conjectured that every n-vertex $(B+3)$-graph has much more than $5n/3$ edges, presented $(B+3)$-graphs with $2n-3$ edges, and suggested that perhaps $2n$ is the asymptotically best lower bound. We prove that indeed every $(B+3)$-graph has at least $2n-3$ edges. Our proof uses a potential function and the connection between orientations and colorings of graphs.

If time permits, I will also present a problem which arose as a possible way to simplify our proofs. This work is ongoing and joint also with Alon, West, and Zhu. (Received September 02, 2014)

1106-VN-601 **Liz Lane-Harvard*** (elaneharvard@uco.edu) and **Tim Penttila** (penttila@math.colostate.edu). *Strongly Regular Graphs from Generalized Quadrangles.* Preliminary report.

There are many open problems dealing with strongly regular graphs: proving non-existence for parameters where none are known; proving existence for parameters where none are known; constructing more for parameters where examples are already known. The work surveyed in this talk falls into the last category. Using the collinearity graph of a generalized quadrangle, new strongly regular graphs will be constructed. (Received September 03, 2014)

1106-VN-604 **Edward D. Kim*** (ekim@uwlax.edu), 1725 State St, La Crosse, WI 54601. *Graphs of polytopes and abstract polytopes.* Preliminary report.

The diameter of polytopes is related to the efficiency of the simplex algorithm used in linear optimization. We will briefly describe the connection. Our approach is to study the diameters of polytopes by studying subset partition graphs, a certain type of abstract polytope. The vertex sets of these graphs satisfy a simple additional combinatorial property related to partitioning a given fixed set. After presenting a complete introduction to polytope and abstract polytope topics relevant for this talk, we present recent lower bounds on diameters for graphs of abstract polytopes and several new results relating the various previous notions of abstract polytopes and their graphs. The talk is completely self-contained and includes collaborations with Tristram C. Bogart and J. Mackenzie Gallagher. (Received September 03, 2014)

1106-VN-725 **J. Mackenzie Gallagher*** (gallaghe.john@uwlax.edu), 1725 State St, Dept of Mathematics, La Crosse, WI 54601. *Diameters of polytope graphs and an improved upper bound on subset partition graphs.* Preliminary report.

The graphs of polytopes are studied in mathematical optimization because of their relation to the simplex method for linear programming. A polytope is the convex hull of a finite set of points, and is a high-dimensional generalization of a convex polygon or polyhedron. They are the set of feasible solutions for linear programs. The study of the diameter of graphs obtained from polytopes is related to the efficiency of the simplex method.

Recently, Kim has introduced subset partition graphs, a generalization of previous abstract polytopes. In 2009, Eisenbrand et al. proved that these previous abstract polytopes satisfied an analogue of the Kalai-Kleitman subexponential bound for polytopes. In 2014, Todd improved the Kalai-Kleitman bound for polytopes. In this talk, we show that an analogue of Todd's bound applies to subset partition graphs. (Received September 05, 2014)

1106-VN-726 **Barbara M Anthony*** (anthonyb@southwestern.edu), 1001 E. University Ave, Georgetown, TX 78626, and **Michael E. Picollelli**. *Complete r-partite graphs determined by their domination polynomial.*

The domination polynomial of a graph is the polynomial whose coefficients count the number of dominating sets of each cardinality. A recent question asks which graphs are uniquely determined (up to isomorphism) by their domination polynomial. In this work, we completely describe the complete r-partite graphs which are; in the bipartite case, this settles in the affirmative a conjecture of Aalipour, Akbari and Ebrahimi. (Received September 05, 2014)

1106-VN-897 **Sarah Hanusch*** (sh1609@txstate.edu), Department of Mathematics, Texas State University, 601 University Drive, San Marcos, TX 78666. *Counting the isomorphism classes of the generalized Petersen graphs.*

The generalized Petersen graphs are a family of graphs with two positive integer parameters n and k, where $k < n$. The graph $GP(n,k)$ contains $2n$ vertices $u_0, u_1, \ldots, u_{n-1}$ and $v_0, v_1, \ldots, v_{n-1}$, and $3n$ edges u_iu_{i+1}, u_iv_i and v_iv_{i+k} where all indices are considered $\mod n$. Results from number theory and graph theory are combined to count the isomorphism classes of the generalized Petersen graphs for each value of $n \geq 5$. (Received September 08, 2014)

1106-VN-1010 **Megan Cream***, mcream@emory.edu, and **Ronald Gould**, **Ralph Faudree** and **Kazuhide Hirohata**. *On Chorded Cycles.*

Historically, there have been many well known results concerning sufficient conditions for finding certain sets of cycles in graphs. Until 1960, *chorded* cycles were greatly ignored. That year, Posa asked: what conditions imply a graph must contain a chorded cycle? This question has since inspired many more questions concerning conditions that guarantee the existence of specific sets of chorded cycles in a graph. Recently, there have been many chorded cycle results considering neighborhood conditions ($|N(x,y)|$) degree sum conditions ($\sigma_2(G)$), and minimum degree conditions ($\delta(G)$). This talk will focus on the new results from the past year– joint work with Ralph Faudree, Ron Gould, and Kazu Hirohata. (Received September 09, 2014)

1106-VN-1021 **John Villalpando*** (jvillalp@callutheran.edu), California Lutheran University, 60 West Olsen Road, Thousand Oaks, CA 91360, and **Vesta Coufal**, **Kathie Yerion** and **Rob Ray**. *The Existence of Trees for Given Values of λ, $\bar{\kappa}$, and κ for $L(2,1)$-Colorings and Irreducible $L(2,1)$-Colorings.*

An L(2,1)-coloring of a graph is a labeling of the vertices using non negative integers such that adjacent vertices differ in label by at least 2 and distance two vertices differ in label. A well studied invariant of $L(2,1)$-colorings, the span denoted by λ, is the smallest integer k for a given graph such that there exists an $L(2,1)$-coloring of the graph using only integers less than or equal to k. The invariant $\bar{\kappa}$ is the least number of color classes required to create an $L(2,1)$-coloring on a given graph. An $L(2,1)$-coloring of a graph is irreducible if reducing the label on any vertex violates an $L(2,1)$-coloring condition. The invariant κ is the least number of color classes required to create an irreducible $L(2,1)$-coloring on a given graph. For any tree T it is known that $\Delta + 1 \leq \bar{\kappa} \leq \kappa \leq \lambda + 1$ and $\lambda \in \{\Delta + 1, \Delta + 2\}$ where Δ is the maximum degree of the tree. We study the 18 possible cases of the values $\bar{\kappa}, \kappa$, and λ on trees providing examples, families of examples or when necessary proving no such tree exists. (Received September 09, 2014)

1106-VN-1054 **Sarah Holliday**, **Jennifer Vandenbussche** and **Erik Westlund*** (`ewestlun@kennesaw.edu`), Kennesaw State University, Department of Mathematics, 1000 Chastain Rd, Kennesaw, GA 30144. *All Graphs are Hall $\Delta(G)$-Completable.*

In the context of vertex list-coloring, Hall's condition is a generalization of Hall's marriage theorem and is necessary (but not sufficient) for a graph to admit a proper list-coloring. A list assignment L to a graph G is called *Hall* if (G, L) satisfy Hall's condition. A graph G is *Hall m-completable* if every partial proper m-coloring of G, whose corresponding list assignment is Hall, can be extended to a proper m-coloring of G. In 2011, Bobga et al. asked if all graphs G are Hall $\Delta(G)$-completable, thereby posing a possible list-coloring variant of Brooks theorem. We give a straightforward and short proof that answers this question in the affirmative, as well as discuss some related results. (Received September 10, 2014)

1106-VN-1067 **Eric J. Landquist*** (`elandqui@kutztown.edu`), Department of Mathematics, Kutztown University, Kutztown, PA 19530. *The Generalized Steiner Cable-Trench Problem with Application to Error Correction in Vascular Imaging.*

In this talk, we will describe the Cable-Trench Problem (CTP), which is an NP-complete graph-theoretic problem that establishes a continuum between the Minimum Spanning Tree and Shortest Path Tree Problems on a weighted graph. We will then define a natural extension of the CTP, called the Generalized Steiner CTP (GSCTP). In the GSCTP, a given subset of the vertex set of the original graph is required to be in the solution tree and each edge has two weights: a "cable" weight and a "trench" weight. The CTP and GSCTP were motivated by the problem of minimizing the cost to dig trenches and lay dedicated cables to connect buildings to a central hub. However, we will focus on the nontrivial and novel application of the GSCTP to the problem of eliminating false-positive results from micro-CT scans of a blood vessel network (vasculature). The vascular imaging problem requires one to digitally reconstruct the vasculature from a discrete set of points and the radii of the blood vessels at those points. Previous methods required manual correction. However, we will show that modifications to Prim's algorithm efficiently find very good approximations to exact solutions to the GSCTP, thus fully automating the error-correction process in our application to vascular image analysis. (Received September 10, 2014)

1106-VN-1112 **Marc J Besson*** (`bessonm@dickinson.edu`), 159 PO Box 1773, Carlisle, PA 17013. *T_r − span of Directed Wheel Graphs.*

This talk covers the results of research into the span of T-colored directed wheel graphs. T-colorings were first introduced by Hale in his 1980 paper on the frequency assignment problem, and are a generalization of proper vertex graph colorings. We extend graph T-Colorings to digraph T-Colorings, and investigate the optimal span of T-Colored wheel digraphs, which are digraphs whose underlying graph is a wheel graph. When T-coloring using the T-set T_r, we prove general bounds for a large class of wheel graphs, as well as determine the specific values for the T-span and optimal colorings of a subset of directed wheel graphs. (Received September 10, 2014)

1106-VN-1177 **Mark Ginn*** (`ginnmc@appstate.edu`) and **Faith Miller**. *The Crossing Number of $K_{3,3,n}$.*

Given a drawing D in the plane of a graph $G = (V, E)$, the crossing number of G with respect to D, $cr_D(G)$ is the number of edge crossings in the drawing. The crossing number of G, $cr(G)$ is the minimum over all drawings D of G of $cr_D(G)$. Extensive work has been done on determining the crossing numbers of complete bipartite graphs of the form $K_{1,m,n}$ and $K_{2,m,n}$. We will explore the crossing number of $K_{3,3,n}$ and give some upper and lower bounds for this number. (Received September 11, 2014)

1106-VN-1372 **Adam Bland*** (`adam.bland@mga.edu`), 100 College Station Dr., Office 219, Mathematics Building, Macon, GA 31210, and **Jeremy Aikin**. *Monochromatic sinks in 3-switched tournaments.* Preliminary report.

Let T be a tournament whose arcs are colored using at most three colors. A cycle C in T is called k-switched if there are at most k vertices in C whose incident arcs in C are two distinct colors. We prove that if every cycle in T of length at least four is 3-switched and every cycle of length three is 2-switched, then T contains a monochromatic sink. This addresses a question posed by Sands, Sauer, and Woodrow in 1982. (Received September 12, 2014)

1106-VN-1373 **Joe DeMaio*** (`jdemaio@kennesaw.edu`) and **John Jacobson** (`johnjacobson8128@gmail.com`). *The Fibonacci Number of the Jellyfish Graph.* Preliminary report.

Given a graph $G = (V, E)$, a set $S \subseteq V$ is an independent set of vertices if no two vertices in S are adjacent. Prodinger and Tichy define the **Fibonacci number of a graph** G, $i(G)$, to be the number of independent sets of the graph. They do so because $i(P_n) = F_{n+2}$ and $i(C_n) = L_n$ where F_n and L_n represent the Fibonacci and Lucas sequences. **The Tadpole Graph**, $T_{n,k}$, is the graph created by concatenating C_n and P_k with an edge from any vertex of C_n to a pendent of P_k for integers $n \geq 3$ and $k \geq 0$. Recent work shows $i\left(T_{n,k}\right) = L_{n+k} + F_{n-3}F_k$ where the resulting triangular array of values yields many interesting properties. Generalizing $T_{n,k}$, we define the **Jellyfish Graph** J as the concatenation of a single C_n and paths $P_{k_1}, P_{k_2}, ..., P_{k_m}$ with an edge from any vertex of C_n to a pendent of P_{k_t} for each $t = 1, 2, ..., m$, for integers $n \geq 3$, $k_t \geq 0$, $m \leq n$ where $\Delta(J) = 3$. In this talk we discuss preliminary results of $i(J)$ for $m = 2$. (Received September 12, 2014)

1106-VN-1467 **Jitender Deogun** and **Tyler Seacrest*** (tyler.seacrest@umwestern.edu), 710 S Atlantic St, Dillon, MT 59725. *A New Proof of Nash-Williams – Tutte and Generalizations to S-connectors.*

A classic result proved independently by Nash-Williams and Tutte characterizes when k edge-disjoint spanning trees pack in a graph. There have been many proofs of this result over the years. In this talk, we give one that is in our opinion particularly nice based off edge-swaps.

West and Wu introduced a generalization of spanning trees called S-connectors. They proved that $10k$ connectivity was sufficient to guarantee k edge-disjoint S-connectors, and conjectured that $3k$ would be sufficient. Using the same technique as our proof of Nash-Williams – Tutte, we prove $9k$ is sufficient. (Received September 13, 2014)

1106-VN-1503 **Ron Gould**, **Victor Larsen*** (vlarsen@emory.edu) and **Luke Postle**. *Asymptotic density of k-critical graphs.*

A graph G is *k-critical* if $\chi(G) = k$ and every proper subgraph $H \subsetneq G$ has $\chi(H) \leq k-1$. Thus, a k-critical graph can be viewed as a minimal k-chromatic graph. A natural question about a minimal k-chromatic graph is how small such a graph can be. For a fixed number of vertices, n, let $f_k(n)$ denote the minimum number of edges in a k-critical graph on n vertices. The Hájos construction (and its generalization, the Ore construction) implies that $f_k(n+k-1) \leq f_k(n) + (k-1)\left(\frac{k}{2} - \frac{1}{k-1}\right)$. Therefore, the asymptotic density φ_k of a k-critical graph as we increase the number of vertices is at most $\frac{k}{2} - \frac{1}{k-1}$. In a 2012 paper, Kostochka and Yancey were able to confirm that $\varphi_k = \frac{k}{2} - \frac{1}{k-1}$, by providing a lower bound on $f_k(n)$. We examine the graphs that attain this bound (the *k-extremal* graphs) and identify key subgraphs. This allows us to obtain an asymptotic density of $\varphi_k + \epsilon$ on k-critical graphs that do not contain these subgraphs. (Received September 13, 2014)

1106-VN-1633 **Erik A Insko*** (einsko@fgcu.edu), **Armando Grez** and **Michael Farina**. *New Upper Bounds on the Distance Domination Numbers of Grids.* Preliminary report.

In his 1992 Ph.D. thesis Chang identified an efficient way to dominate $m \times n$ grid graphs and conjectured that his construction gives the most efficient dominating sets for relatively large grids. In 2011 Gonçalves, Pinlou, Rao, and Thomassé proved Chang's conjecture, establishing a closed formula for the domination number of a grid. In March 2013 Fata, Smith and Sundaram established upper bounds for the k-distance domination numbers of grid graphs by generalizing Chang's construction of dominating sets to k-distance dominating sets. In this paper we use algebraic and geometric arguments to improve the upper bounds established by Fata, Smith, and Sundaram for the k-distance domination numbers of grids. (Received September 14, 2014)

1106-VN-1777 **Brent Moran*** (brent.moran@ucdenver.edu), **Matt Mowrey** (matthew.mowrey@ucdenver.edu) and **Michael Ferrara** (michael.ferrara@ucdenver.edu). *Ramsey-Minimal Saturation Numbers for Sets of Stars.*

A graph G is *$\mathcal{F}$-saturated* for a family $\mathcal{F}$ of graphs if G contains no member of $\mathcal{F}$ as a subgraph, but for any edge $e \in E(\overline{G})$, some member of $\mathcal{F}$ is a subgraph of $G + e$. The *saturation number* $\text{sat}(n, \mathcal{F})$ is the minimum number of edges in an $\mathcal{F}$-saturated graph of order n. If $\mathcal{F} = \{F\}$ for a single graph F, we say G is *F-saturated*, denoted $\text{sat}(n, F)$.

Given a set $\{H_1, \ldots, H_k\}$ of graphs, a graph G is called $(H_1, \ldots, H_k)$*-Ramsey-minimal* if every k-coloring of $E(G)$ contains some H_i in color i, but for any edge $e \in E(G)$, some k-coloring of $G - e$ does not. We denote the family of $(H_1, \ldots, H_k)$-Ramsey-minimal graphs by $\mathcal{R}_{\min}(H_1, \ldots, H_k)$.

Motivated in part by a 1987 conjecture of Hanson and Toft, we prove a number of results about Ramsey-minimal saturation numbers for sets of stars. In particular, we give an upper bound on $\text{sat}\big(n, \mathcal{R}_{\min}(K_{1,t_1}, \ldots, K_{1,t_p})\big)$ for arbitrary $t_1, \ldots, t_p$, and show that it is sharp when $p = 2$ and in several other cases. (Received September 15, 2014)

1106-VN-1794 **Jennifer Diemunsch*** (jennifer.diemunsch@ucdenver.edu), **Michael Ferrara**, **Sogol Jahanbekam** and **James Shook**. *Extremal Theorems for Degree Sequence Packing.*

A sequence $\pi = (d_1, \ldots, d_n)$ is graphic if there is a simple graph G with vertex set $\{v_1, \ldots, v_n\}$ such that the degree of v_i is d_i. Two graphic sequences $\pi_1 = (d_1^{(1)}, \ldots, d_n^{(1)})$ and $\pi_2 = (d_1^{(2)}, \ldots, d_n^{(2)})$ pack if there exist edge-disjoint n-vertex graphs G_1 and G_2 such that for $j \in \{1, 2\}$, $d_{G_j}(v_i) = d_i^{(j)}$ for $i \in \{1, \ldots, n\}$. In this talk, we will present two new extremal results on graphic sequence packing. In particular, we give degree sequence analogues to the widely-studied Bollobás-Eldridge-Catlin conjecture for graph packing as well as a degree sequence version of the classical graph packing theorem of Sauer and Spencer. (Received September 15, 2014)

1106-VN-1845 **Tung Hoang*** (hoangt@millsaps.edu), 150660 Millsaps College, 1701 North State Street, Jackson, MS 39210. *Some Results on Path Localities of Completed Bipartite Graphs.*

In everyday life, many people encounter the need of arranging objects from high-dimensional space into low-dimensional space while best preserving the relationships between them. For instance, grocery store owners want to arrange their products into online column lists such that the nearby products in their store are close to each other in the lists; computer developers want to improve the burst-mode by optimally arranging data into linear addresses; or engineers want to best order the tasks for space robots so that the robots can work efficiently and productively. Motivated by these needs, in 2012, Dr. Yan Wang and David Poliakoff from Millsaps College built a graph theory model and introduced the concept of locality – a parameter measuring how well the distance relationships between vertices in one graph are preserved while those vertices are arranged into another graph. Continuing their research, I apply the idea of locality to find the best arrangement of the vertices in completed bipartite graphs into paths. In my presentation, I will introduce the results of the best arrangement for three types of completed bipartite graphs: $K_{1,n}, K_{2,n}$, and $K_{3,n}$; and my conjecture for the general case $K_{m,n}$. (Received September 15, 2014)

1106-VN-1873 **Kim A. S. Factor*** (kim.factor@marquette.edu), Milwaukee, WI 53201. *Complete (i,j)-domination graphs of tournaments.* Preliminary report.

Domination in graphs has been popular for decades and sports a large following. From the graph-based domination grew domination graphs, founded upon the idea of domination between vertices in a digraph. In the spirit of the initial link between domination and domination graphs, in 2010 Factor and Langley extended the idea of (i, j)-domination in graphs (Hedetniemi *et al.*) to domination graphs. Given a digraph D, the (i, j)-domination graph of D, $\mathrm{dom}_{i,j}(D)$, has the same vertex set as D with edge uv if for every vertex z in $\mathcal{V}(D) - \{u, v\}$, u reaches z in at most i steps and v reaches z in at most j steps. Results have been found for tournaments with specific values of i and j. Here, a combinatorial approach is taken and the minimum values of i and j are determined for certain classes of tournaments for which an (i, j)-domination graph exists that is a complete graph. (Received September 15, 2014)

1106-VN-1875 **James M Hammer*** (jmh0036@auburn.edu), 426 North Donahue Dr, Apt 6, Auburn, AL 36832. *Taking Sudoku a Step Further.*

Sudoku has risen in popularity over the past few years. The rules are simple, yet the solutions are often less than trivial. Mathematically, these puzzles are interesting in their own right. This presentation will use the idea of a Sudoku Puzzle to define a new kind of $n \times n$ array. Further, we will aim to prove some necessary (and on occasion sufficient) conditions for the existence of these arrays. To that end, we define a latin square of order n as an $n \times n$ array where every row and every column contain every symbol $1, 2, \ldots, n$ exactly once. We say $a \times b$ is an ordered factor pair of the integer n if $n = a \times b$. An (a, b)-Sudoku latin square is a latin square where in addition to each row and column containing every symbol exactly once, each $a \times b$ rectangle also contains every symbol exactly once when the $n \times n$ array is tiled with $a \times b$ rectangles in the natural way. A factor pair latin square of order n (denoted FPLS(n)) is an (a, b)-Sudoku latin square for every factor pair (a, b) of n. This presentation will mainly be concerned with the existence of such designs as well as related problems to such designs. (Received September 15, 2014)

1106-VN-1992 **Aras Erzurumluoglu*** (aze0009@auburn.edu) and **Chris Rodger** (rodgec1@auburn.edu). *Fair 1-factorizations, fair holey 1-factorizations and fair holey hamiltonian decompositions of complete multipartite graphs.*

A k-factor of G is a k-regular spanning subgraph of G. A k-factorization is a partition of $E(G)$ into k-factors. Let $K(n, p)$ be the complete multipartite graph with p parts, each of size n. If $V_1, \ldots, V_p$ are the p parts of $V(K(n, p))$, then a holey k-factor of deficiency V_i of $K(n, p)$ is a k-factor of $K(n, p) - V_i$ for some i. Hence a holey k-factorization is a set of holey k-factors whose edges partition $E(K(n, p))$. In particular a holey hamiltonian decomposition is a holey 2-factorization of $K(n, p)$ where each holey 2-factor is a connected subgraph of $K(n,p) - V_i$ for some i. A (holey) k-factorization of $K(n,p)$ is said to be fair if between each pair of parts the color classes have size within one of each other. In this work the existence of fair 1-factorizations, fair holey 1-factorizations and fair holey hamiltonian decompositions of $K(n,p)$ are completely settled. The second result can be used to construct symmetric quasigroups of order np with holes of size n with the additional property that the permitted symbols are shared as evenly as possible among the cells in each $n \times n$ "box". The third result simultaneously settles the existence of cycle frames of type n^p for cycles of the longest length. (Received September 15, 2014)

1106-VN-2031 **Annette Marie Honken*** (annette-honken@uiowa.edu), Department of Mathematics, University of Iowa, 14 Maclean Hall, Iowa City, IA 52242. *Mapping Distance One Neighborhoods within Knot Distance Graphs.* Preliminary report.

A knot can be thought of as a knotted piece of string with the ends glued together. To perform a crossing change on a knot, one can imagine cutting one string, allowing the other string to pass through, and gluing the cleaved ends back together. We define the distance between two knots, K_1 and K_2, to be the minimum number of crossing changes one must perform on either K_1 or K_2 to obtain the other. Type II topoisomerases are the enzymes tasked with keeping DNA unknotted, and they act on double-stranded circular DNA by breaking the backbone of the DNA, allowing another segment of DNA to pass through, and re-sealing the break. Thus, performing a crossing change on a knot models the action of this protein.

We create a knot distance graph by letting the set of vertices be knots with up to thirteen crossings and placing an edge between any two knots of distance one. A neighborhood of a vertex, v, in a graph is the set of vertices with which v is incident via an edge. Using graph theoretical and topological tools, we examine graphs of knot distances and define a mapping of distance one neighborhoods. This idea can also be examined and visualized as Dehn surgery on the double-branched cover of a knot. (Received September 15, 2014)

1106-VN-2084 **Meng Zhang*** (mzhang4@mix.wvu.edu), 320 Armstrong Hall, P.O. Box 6310, West Virginia University, Morgantown, WV 26505. *Spanning trail with Independence number.*

An independent set S of graph G is a vertex subset such that any two vertices in S do not adjacent with each other. The independence number of graph G, denoted by $\alpha(G)$, is the cardinality of the maximum independent set in G. Let $\kappa'(G)$ denote the edge connectivity of G. I proved that If $\kappa'(G) \geq \max\{2, \alpha(G) - 3\}$, then G has a spanning trail. This improves the former result. (Received September 15, 2014)

1106-VN-2091 **Keke Wang*** (kwang6@mix.wvu.edu), 320 Armstrong Hall, P.O.BOX 6310, Morgantown, WV 26506. *Strongly Spanning Trailable Graphs with Short Longest Paths.*

For a graph G and edges $e = u_1v_1, e' = u_2v_2 \in E(G)$, the graph $G(e, e')$ is obtained from G by replacing $e = u_1v_1$ by a path $u_1v_ev_1$ and by replacing $e' = u_2v_2$ by a path $u_2v_{e'}v_2$, where $v_e, v_{e'}$ are two new vertices not in $V(G)$. A graph G is strongly spanning trailable if for any $e = u_1v_1, e' = u_2v_2 \in E(G)$, $G(e, e')$ has a spanning $(v_e, v_{e'})$-trail. Luo et al. [Discrete Mathematics 306 (2006) 87-98] proved that every 4-edge-connected graph is spanning trailable. In this paper, we show that, for a 3-edge-connected graph G which is not the Wagner graph, if every pair of edges is joined by a longest path of length at most 8, then G is strongly spanning trailable. (Received September 15, 2014)

1106-VN-2187 **Thomas P. Reith*** (threith@davidson.edu) and **Laurie J. Heyer** (laheyer@davidson.edu). *Motif-based clustering of directed networks.* Preliminary report.

The study of networks has become increasingly relevant in a variety of scientific fields, including biology, sociology, and computing. It has been shown that many real networks divide naturally into clusters, or communities, of related vertices. A large amount of research has focused on the detection of such clusters in undirected networks; their detection in directed networks, however, is a less well-studied problem. Here we introduce a novel clustering algorithm for directed graphs based on the concept of network motifs – recurrent, statistically significant subgraphs found at higher frequencies in real networks than ones that are randomly generated. (Received September 16, 2014)

1106-VN-2195 **Max L. Goering*** (mlgoering@gmail.com), 915 Denison Ave. Apartment 6, Manhattan, KS 66502. *Modulus of families of walks on graphs.*

We introduce the notion of modulus of families of walks on graphs. We use Beurling's criterion for extremality, which we show can be interpreted on graphs as an instance of the Karush-Kuhn-Tucker conditions, as a guiding light to develop an algorithm that numerically computes the modulus. (Received September 16, 2014)

1106-VN-2277 **Susan C. White*** (scwhite@bellarmine.edu), Mathematics Department, Bellarmine University, 2001 Newburg Road, Louisville, KY 40205, and **Adam S. Jobson** and **André E. Kézdy**. *Connected Matchings in Chordal Bipartite Graphs.*

A connected matching M in a graph G is a collection of pairwise disjoint edges such that every pair of edges of M is joined by an edge of G. Motivated by applications to Hadwiger's conjecture, Plummer, Stiebitz, and Toft introduced connected matchings and proved that, given a positive integer k, determining whether a graph has a connected matching of size at least k is NP-complete. Cameron proved that this problem remains NP-complete on bipartite graphs, but can be solved in polynomial-time on chordal graphs. We present a polynomial-time algorithm that finds a maximum connected matching in a chordal bipartite graph. We give several applications of the algorithm, including computing the Hadwiger number of a chordal bipartite graph. (Received September 16, 2014)

1106-VN-2303 **Misa Nakanishi*** (nakanishi@2004.jukuin.keio.ac.jp). *The domination number and the independent domination number for a bipartite graph.*

In this paper, a graph G = (V, E) is simple. A set of vertices X such that $N_G[X] = V$ is called a dominating set. The minimum cardinality taken over all minimal dominating sets or all maximal independent sets of G is the domination number $\gamma(G)$ or the independent domination number $i(G)$ respectively. A sufficient condition for $\gamma(G) = i(G)$ was represented in 1978, $K_{1,3}$ - free. A subgraph I is defined as two adjacent vertices v and w and its neighbors such that $d_I(v) \geq 3$ and $d_I(w) \geq 3$. We observe I as a forbidden subgraph for $\gamma(G) = i(G)$ with a simplest proof. A property of I is remarkable for dominating sets of a graph. It characterized 3-connected graphs, where $i(G)$ and $\gamma(G)$ are significantly different indicated in 1994.

We have a different approach to the domination number formulation. A bipartite graph G is decomposed by I, which is $G = I_1 \cup \cdots \cup I_k \cup F$ pairwise disjoint. $\gamma(G_1 \cup G_2) \leq \gamma(G_1) + \gamma(G_2)$ for arbitrary graphs G_1 and G_2. On the basis of it, we present a sufficient condition led to an equation $\gamma(G) = \gamma(I_1) + \cdots + \gamma(I_k) + \gamma(F) = 2k + i(F)$. The k-dominating graph $D_k(G)$ defined in 2014 explains the proof of Theorem. (Received September 16, 2014)

1106-VN-2445 **Aquia Richburg***, 830 Westview Dr. SW, Atlanta, GA 30314, and **Shannon Jordan**, **Roger Licairac** and **Eugene Fiorini**. *Forbidden Subgraphs of Competition Graphs on Doubly Partial Orders.*

Let D=(V,A) be an acyclic digraph with vertex set V, ordered by reachability, and directed edge set A. The competition graphC(D) = (V,E) is an undirected graph with the same vertex set as D and an edge (x,y) between distinct vertices x,y in V if there exists a vertex u in V such that (x,u), (x,u) in A. If x and y are connected in C(D), they are said to be in competition. Competition graphs have application in coding, radio transmission and modeling of complex economic systems. This paper classifies forbidden subgraphs of competition graphs on a doubly partial order. These results are extended to competition graphs on n-tuply partial order sets and correlation to Dyck paths and Catalan numbers is discussed. (Received September 16, 2014)

1106-VN-2460 **Suil O*** (suilo@gsu.edu). *Edge-connectivity in regular multigraphs from eigenvalues.*

Let G be a d-regular multigraph, and let $\lambda_2(G)$ be the second largest eigenvalue of G. In this talk, we prove that if $\lambda_2(G) < \frac{d-1+\sqrt{9d^2-10d+17}}{4}$, then G is 2-edge-connected. Furthermore, for $t \geq 2$ we show that G is $(t+1)$-edge-connected when $\lambda_2(G) < d-t$, and in fact when $\lambda_2(G) < d-t+1$ if t is odd. (Received September 16, 2014)

1106-VN-2463 **Steven Schluchter*** (sschluch@gmu.edu), Department of Mathematical Sciences, George Mason University, 4400 University Drive, MS: 3F2, Fairfax, VA 22030. *Applications of ordinary voltage graph theory to graph embeddability, parts 1 and 2.*

We will develop and apply our homologically driven matrix analysis to the study of ordinary voltage graph embeddings. An ordinary voltage graph embedding is an assignment of algebraic data to the directed edges of a cellularly embedded graph, which encodes a highly symmetric embedding, called the derived embedding, of the derived graph in the derived surface. It is a consequence of ordinary voltage graph theory that if a graph G is cellularly embedded in a surface S in such a way that a free action of a group A on G extends to a cellular automorphism of S, then the embedding can be encoded in the form of an ordinary voltage graph embedding. We will show that for each prime p > 5, the generalized petersen graph GP(2p,2) can be embedded in the torus, but not as a derived embedding. Furthermore, we will show that for each prime q > 3, there exists an ordinary voltage graph that has no derived embedding in the nonorientable surface of Euler characteristic 2-2q, yet the corresponding derived graph does have an embedding in this surface. (Received September 16, 2014)

1106-VN-2492 **Oscar Levin** (oscar.levin@unco.edu), School of Mathematical Sciences, University of Northern Colorado, Greeley, CO 80639, and **Catrina Myrant*** (myra9229@bears.unco.edu). *Coloring Around Faces to Count Daisies.*

A planar graph is one that can be drawn in the plane without edges crossing. However this embedding need not be unique. To distinguish between different embeddings of a single planar graph we introduce the *face-wise chromatic number*. This is analogous to the usual chromatic number, except now we require vertices incident to the same face to be colored distinctly. We will investigate the face-wise chromatic number for a particular class of graphs called *daisy graphs*. This will give insight into the behavior of the face-wise chromatic number and conversely suggests a way to classify different planar embeddings of these graphs. (Received September 16, 2014)

1106-VN-2565 **Cynthia I Wood*** (ciw2@rice.edu), 6100 Main st - MS 134, Houston, TX 77005. *The Maximum Weighted Co-2-Plex Problem in a {Claw, Bull}-Free Graph.*

The maximum weighted co-2-plex problem (MWC2P) determines a subset of vertices of maximum total weight of a given graph, in which each vertex has degree at most one. This talk presents a polynomial time algorithm for solving MWC2P problem in {claw, bull}-free graphs. (Received September 16, 2014)

1106-VN-2579 **Matthew Jura** (matthew.jura@manhattan.edu) and **Oscar Levin*** (oscar.levin@gmail.com), School of Mathematical Sciences, University of Northern Colorado, Greeley, CO 80639, and **Tyler Markkanen** (tmarkkanen@springfieldcollege.edu). *Controlling Domination in Infinite Graphs.*

A set of vertices in a graph is *dominating* if every vertex not in that set is adjacent to a vertex in the set. A partition of the vertices into dominating sets is called a *domatic partition*. Motivated by questions in effective graph theory, we are interested in ways the structure of infinite graphs might control the number and types of domatic partitions present in the graphs. For example, we will show that you can build a graph which contains an infinite set of vertices which must all belong to the same dominating set in any domatic partition of a particular size. In this talk we will explore a variety of results of this sort as well as consider what happens for related notions of domination, such as total, independent, or paired domatic partitions. (Received September 16, 2014)

1106-VN-2620 **Jill Bigley Dunham*** (jillbd@gmail.com), 20400 Spectrum, Irvine, CA 92618, and **Gwyneth R Whieldon**. *Enumeration of Solutions to a Paper Cutting and Folding Problem by Martin Gardner.*

A classic puzzle appearing in Martin Gardner's *New Mathematical Diversions* asks if (and how) it is possible to cut a 3×3 piece of paper divided into 1×1 squares along the grid, keeping the paper connected, so that the paper may be folded to wrap a unit cube. In this talk, we enumerate all solutions to the puzzle, classifying them using 8-edge subgraphs of the underlying lattice adjacency graph of the paper. We also break the solutions into two subclasses – solutions which can be folded so that only one side of the original paper is visible after the wrapping (*monocolored* solutions), and solutions such that both sides of the paper will be visible on the cube surface. (Received September 16, 2014)

1106-VN-2661 **Zoltan Furedi** and **Sogol Jahanbekam*** (sogol.jahanbekam@ucdenver.edu). *Maximum number of edges in digraphs with specified weak diameter.*

The weak distance between two vertices in a digraph G is the length of a shortest directed path connecting these two vertices. The weak diameter of a digraph G is the longest weak distance among all pairs of vertices in G. We define $w(n, d)$ to be the smallest number of edges a digraph G with n vertices and weak diameter d can have. We determine $w(n, d)$, whenever n is large enough as a function of d. This is joint work with Zoltan Füredi. (Received September 16, 2014)

1106-VN-2684 **James Abello** (abello@dimacs.rutgers.edu), **David DeSimone*** (djd231@scarletmail.rutgers.edu) and **Mika Sumida** (sumidami@gmail.com). *Graph Cards.*

We describe a graph based approach to represent data collections where the members of the collection are comparable to each other via some similarity measure. The central idea is to define a "card" abstraction for each member of the collection. Each card contains condensed information describing the main characteristics of a particular collection member. The card collection can be interactively explored, by a user, via window panning, zooming, and mouse hovering, dragging and clicking. Our system also offers a card trading mechanism where users can virtually buy or sell collection cards. Cards have a value that is dynamically computed as a function of several parameters that include their popularity, demand, and level of similarity to other cards in the collection.

We have tested our current implementation with several data bases including the DIMACS REU projects since 1996. (Received September 16, 2014)

1106-VN-2761 **David Blessing*** (dblessing2014@fau.edu), 5110 Atlantic Ct., Cape Coral, FL 33904, **Katie Johnson**, FL, and **Erik Insko** and **Christie Mauretour**. *On* (t, r) *Broadcast Domination Numbers of Grids.*

The domination number of a graph $G = (V, E)$ is the minimum cardinality of any subset $S \subset V$ such that every vertex in V is in S or adjacent to an element of S. Finding the domination numbers of m by n grids was an open problem for nearly 30 years and was finally solved in 2011 by Goncalves, Pinlou, Rao, and Thomassé. Many variants of domination number on graphs have been defined and studied, but exact values have not yet been obtained for grids. We will define a family of domination theories parameterized by pairs of positive integers (t, r) where $1 \leq r \leq t$ which generalize domination and distance domination theories for graphs. We call these domination numbers the (t, r) broadcast domination numbers. We give the exact values of (t, r) broadcast domination numbers for small grids, and we identify upper bounds for the (t, r) broadcast domination numbers for large grids and conjecture that these bounds are tight for sufficiently large grids. (Received September 16, 2014)

1106-VN-2767 **Janet Fierson*** (fierson@lasalle.edu), Dept. of Mathematics and Computer Science, La Salle University, 1900 W. Olney Ave., Philadelphia, PA 19141. *Coloring graphs and rainbow connection.* Preliminary report.

We introduce a new problem that links two topics in chromatic graph theory that have previously been studied independently: coloring graphs and rainbow connection. Given a graph G and positive integer k, the k-coloring graph of G is the graph with vertex set the proper k-colorings of G and edges between colorings that differ on exactly one vertex. In an edge-colored graph, a path is said to be a rainbow path if no two of its edges share a color; an edge-colored (but not necessarily properly edge-colored) graph is rainbow-connected if a rainbow path exists for every pair of vertices. The concept of the coloring graph has been investigated in the context of vertex coloring and edge coloring. We present a definition and results for the coloring graph as it applies to rainbow connection. (Received September 16, 2014)

1106-VN-2897 **Zena Coles**, **Alana Huszar**, **Jared Miller** and **Zsuzsanna Szaniszlo*** (zsuzsanna.szaniszlo@valpo.edu). *4-equitable Tree Labelings.*

A $4-$equitable labeling of a graph is an assignment of labels $\{0, 1, 2, 3\}$ to the vertices. The edge labels are the absolute difference of the labels of the vertices that they are incident to. The labels must be distributed as evenly as possible amongst the vertices and they must also be distributed as uniformly as possible amongst the edges. We study $4-$equitable labelings of different trees; we found that all caterpillars, symmetric generalized $n-$stars (or symmetric spiders), and complete $n-$ary trees for all $n \in \mathbb{N}$ are $4-$equitable. We believe that proving all trees are 4-equitable will bring us one step closer to proving the famous graceful tree conjecture that has been open for half a century. (Received September 17, 2014)

General Session on Research in Linear Algebra

1106-VO-114 **Brydon Eastman**, **In-Jae Kim**, **Bryan Shader** and **Kevin N. Vander Meulen***, Department of Mathematics, Redeemer University College, Ancaster, Ontario L9K 1J4, Canada. *Companion Matrix Developments.*

The most familiar companion matrix is sometimes called the Frobenius companion matrix. In general, we define a companion matrix A to be an order n matrix with $n^2 - n$ fixed entries and n variable entries, $-a_1, -a_2, \ldots, -a_n$, such that the characteristics polynomial of A is $x^n + a_1x^{n-1} + \cdots + a_{n-1}x + a_n$. In 2003, Fiedler introduced a new class of companion matrices which includes the Frobenius companion matrix as a special case. Each Fiedler companion matrix has $n - 1$ nonzero fixed entries and n variable entries; we say that such a companion matrix is sparse. We show that not all companion matrices are sparse and provide both a matrix and digraph characterization of all the sparse companion matrices. We note that each sparse companion matrix, including each Fiedler companion matrix, is permutationally equivalent to a unit Hessenberg matrix. (Received July 18, 2014)

1106-VO-375 **Joshua Boone*** (josh.boone@lmunet.edu), 6965 Cumberland Gap Parkway, Hamilton Math & Science Building, Rm 330, Harrogate, TN 37752. *The n-th Power of a General 2x2 Matrix.* Preliminary report.

Even for small values of $n \in \mathbb{Z}$, it is sometimes helpful to find M^n, the n-th power of a square matrix M, without explicitly multiplying n copies of M together. We will show two interpretations and formulas for M^n when $M \in GL(2, \mathbb{Z})$. A new recursive construction of a formula will be given for the case where M represents a linear fractional transformation. We will then determine when it is possible to find a transformation of a given order n and give an explicit formula for these cases. (Received August 26, 2014)

1106-VO-817 **Charles Puelz*** (cpuelz@rice.edu), **Mark Embree** and **Jake Fillman**. *An $O(N^2)$ Eigenvalue Algorithm for Period–N Jacobi Operators.*

Aperiodic physical systems may be mathematically modeled by quasiperiodic Jacobi operators, popular examples of which include Fibonacci, period doubling, and Thue-Morse operators. Their spectra yield beautiful and interesting mathematical and physical insight. For example, some spectra are provably Cantor sets, and one can use these objects to study electron propagation in quasicrystals. A useful technique in studying these sets is to approximate them with the spectra of related *periodic* Jacobi operators of increasingly long period. These periodic spectra may be computed as eigenvalues of matrices, whereby we arrive at a challenging largescale eigenvalue problem in which all the eigenvalues (often clustered) are required. We present an $O(N^2)$ eigenvalue algorithm for computing the spectrum of a general period–N Jacobi operator, and then we apply this method to study relevant quasperiodic operators. (Received September 07, 2014)

1106-VO-873 **Andrew J. Klimas*** (aklimas@xula.edu), Xavier University of Louisiana, Department of Mathematics, One Drexel Drive, New Orleans, LA 70125. *The Construction of Faces of* CP_2. Preliminary report.

This paper on the faces of the cone $\pi(PSD_n)$ of positive semidefinite-preserving linear transformations on the complex vector space of complex matrices of order n and its self-dual subcone $\mathrm{CP_n}$ of the completely positive linear transformations explores in particular the construction of faces of CP_2. Carefully-chosen matrices can be used to construct faces of CP_2 of dimensions 1, 4, 9, and 16. Using a characterization due to Kye, it can be determined whether any such face lies in the boundary or interior of $\pi(PSD_2)$. If a face of CP_2 contains an element that lies in the interior of $\pi(PSD_2)$, it follows that the face cannot be a face of $\pi(PSD_2)$. Some faces of CP_2 can be shown to lie in the boundary of $\pi(PSD_2)$ while others can be shown to indeed lie in the interior of $\pi(PSD_2)$. A number of cases are open questions. (Received September 08, 2014)

1106-VO-913 **D. Steven Mackey** and **Vasilije Perovic*** (vasilije.perovic@wmich.edu), 1903 W. Michigan Ave, Mathematics Department, Kalamazoo, MI 49008-5248. *Linearizations of matrix polynomials in non-standard bases.* Preliminary report.

We consider nonlinear eigenvalue problems $P(\lambda)x = 0$ where $P(\lambda)$ is a matrix polynomial of the form

$$P(\lambda) = A_k\phi_k(\lambda) + A_{k-1}\phi_{k-1}(\lambda) + \cdots + A_0\phi_0(\lambda)\,, \tag{1}$$

the A_i's are $n \times n$ complex matrices, and $\{\phi_i(\lambda)\}_{i=0}^{k}$ is a non-standard basis for the space of scalar polynomials of degree at most k. Matrix polynomials as in (1) may arise either directly from applications or when solving non-polynomial eigenvalue problems via polynomial approximation.

The classical approach to the polynomial eigenproblem $P(\lambda)x = 0$ is to convert it into a larger but equivalent eigenproblem $L(\lambda)x = 0$ with $\deg L = 1$; such an L is a *linearization* for P. For this conversion it is important to avoid reformulating P into the standard basis, since this change of basis can be poorly conditioned, and may introduce numerical errors. We show how to systematically generate large new families of linearizations for P by working directly with the matrix coefficients from (1); the polynomial bases we consider include Bernstein, Newton, and Lagrange bases. (Received September 08, 2014)

1106-VO-1009 **Somantika Datta** and **Jesse Ernest Oldroyd*** (jesseo@uidaho.edu), Moscow, ID 83844. *A New Construction of Tight Frames Using Orthogonal Vectors.*

Consider a collection of N unit vectors $\{f_1, \ldots, f_N\}$ in $\mathbb{C}^d$. This set is called an equiangular tight frame (ETF) if the cross-correlation between any two distinct vectors has the same modulus that is given by the Welch bound. ETFs have many properties useful for signal processing and other areas and so their construction has become an important problem in applied harmonic analysis. Unfortunately, ETFs do not always exist for all choices of N and d; therefore it is useful to determine tight frames with a restricted number of distinct cross-correlations. The main focus of this talk is a method to construct such tight frames for all choices of N and d. (Received September 09, 2014)

1106-VO-1241 **Sean Eastman*** (sean.eastman@armstrong.edu). *The volume of the spatial region corresponding to $n \times n$ correlation matrices.*

Given a symmetric, square matrix with 1's on the diagonal and the remaining entries chosen randomly from $(-1, 1)$, the probability that a valid correlation matrix is constructed decreases dramatically as n increases. For 3×3 matrices, the subset of the unit cube consisting of valid correlation matrices can be visualized geometrically as a peculiar shape with volume $\pi^2/2$. In this talk, we utilize a spherical form of the Cholesky decomposition to derive a general formula for volumes (and thus probabilities) of correlation matrices in higher dimensions. (Received September 11, 2014)

1106-VO-1910 **Russell L Carden*** (russell.l.carden@uky.edu), 719 Patterson Office Tower, Lexington, KY 40506-0027, and **Josef Sifuentes**. *The Normal Hessenberg completion and Poncelet's Theorem.*

Motivated by the Hessenberg matrices that arise in Krylov based methods such as the Generalized Residual Method (GMRES) for solving linear systems and the restarted Arnoldi method for computing eigenvalues, we consider the Hessenberg normal completion problem: given a non-normal upper Hessenberg $H \in \mathbb{C}^{n \times n}$ does there exists a normal upper Hessenberg matrix $H_N \in \mathbb{C}^{(n+k)\times(n+k)}$ such that its leading $n \times n$ principal sub-matrix is H. We provide sufficient conditions on k and the normal difference of H that ensure a normal upper Hessenberg completion exists. For $k = 1$, we show nice connections to and possible generalizations of Poncelet's Theorem. We also explore the implications of our results on the observation of Greenbaum, Ptak and Strakos regarding any possible GMRES convergence curve being achievable by some unitary matrix. (Received September 15, 2014)

1106-VO-2307 **Mutlu Akar*** (makar@yildiz.edu.tr), Yildiz Technical University, College of Arts, and Sciences, Mathematics Department, Davutpasa Campus, Esenler, 34210 Istanbul, Turkey, **Serdal Sahin** (sersahin@yildiz.edu.tr), Yildiz Technical University, College of Arts, and Sciences, Mathematics Department, Davutpasa Campus, Esenler, 34210 Istanbul, Turkey, and **Salim Yuce** (sayuce@yildiz.edu.tr), Yildiz Technical University, College of Arts, and Sciences, Mathematics Department, Davutpasa Campus, Esenler, 34210 Istanbul, Turkey. *Higher-Order Velocities and Accelerations under the One-Parameter PlanarDual Motions.*

In this paper, after a brief summary of one-parameter planar dual motions, we introduce the higher-order velocities and accelerations under the one-parameter planar dual motions. (Received September 16, 2014)

1106-VO-2558 **Rachid Marsli*** (rmarsli1@student.gsu.edu). *Extensions of Gersgorin Theory.*

For an eigenvalue of a matrix A, with geometric multiplicity k, we show that the eigenvalue is in at least k Gersgorin discs of A. Some related results and examples will be provided. (Received September 16, 2014)

1106-VO-2794 **Richard A Brualdi** and **Seth A Meyer*** (seth.meyer@snc.edu), St Norbert College, 100 Grant St, De Pere, WI 54115. *A Gale-Berlekamp Permutation-Switching Problem.*

In the spirit of the light switching game of Gale and Berlekamp, we define a light switching game based on permutations. We consider the game over the integers modulo k, that is, with light bulbs in an $n \times n$ formation, having k different intensities cyclically switching from 0 (off) to $(k-1)$ (highest intensity) and then back to 0 (off). Under permutation switching, that is, adding a permutation matrix modulo k, given a particular initial pattern, we investigate both the smallest number $\mathcal{R}_{n,k}$ of on-lights (the covering radius of the code generated) and the smallest total intensity $\mathcal{I}_{n,k}$ that can be attained. We obtain an explicit formula for $\mathcal{I}_{n,k}$ when n is a multiple of k. We also determine $\mathcal{R}_{n,k}$ when k equals 2 and 3. In general, we obtain some bounds for $\mathcal{R}_{n,k}$ and $\mathcal{I}_{n,k}$. (Received September 16, 2014)

1106-VO-2805 **Miroslav Fiedler**, **Frank J. Hall** and **Mikhail Stroev*** (mstroev1@gsu.edu), Georgia State University, Atlanta, GA 30303. *Dense Alternating Sign Matrices and Extensions.*

An alternating sign matrix, henceforth abbreviated ASM, is an $n \times n$ $(0, +1, -1)$-matrix without zero rows and columns,such that the $+1$s and -1s alternate in each row and column, beginning and ending with a $+1$. The substantial interest in ASMs in the mathematics community originated from the alternating sign matrix conjecture of Mills et al. in 1983 and has continued in several combinatorial directions. In this talk, some connections of alternating sign matrices with total unimodularity, combined matrices, and generalized complementary basic matrices are explored. In particular, it is shown that every "dense" ASM is a network matrix, and hence is totally unimodular. (Received September 16, 2014)

General Session on Research in Logic or Foundations

1106-VP-1989 **Demitri J. Plessas*** (plessas@nsuok.edu), 611 N. Grand Ave., Northeastern State University, Dept. of Mathematics and Computer Science, Tahlequah, OK 74464. *An Elementary Theory of the Categories of Graphs.*

The most common category considered in (undirected) graph theory is a category where graphs are defined as having at most one edge incident to any two vertices and at most one loop incident to any vertex. The morphisms are usually described as a pair of functions between the vertex sets and edge sets that respect edge incidence. We will relax these conditions to allow multiple edges to be incident to any two vertices, multiple loops to be incident to any vertex, and morphisms will be allowed to map edges to vertices, but they must still preserve edge incidence. With combinations of these three relaxations we define five categories of graphs.

We follow the lead and spirit of F. W. Lawvere's groundbreaking characterization of the Category of Sets and Functions and D. Schlomiuk's characterization of the Category of Topological Spaces and Continuous Functions. In both characterizations, a list of elementary axioms are provided so that when combined with a higher order axiom a functor equivalence between the axiomatically defined category and the concrete category is formed. We provide such an elementary theory for the five categories of graphs. (Received September 15, 2014)

General Session on Research in Number Theory

1106-VQ-43 **Nick Bogatirev*** (guitarzite@gmail.com). *Prime number pattern Having stated that;the distance's between consecutive squares are odd.* Preliminary report.

All non-prime odd integers are sequences of differences of non-consecutive pairs of odd and even squares,$9 = 3^2 - 0^2$, $15 = 4^2 - 1^2$, $21 = 5^2 - 2^2$...27...33...$25 = 5^2 - 0^2$, $35 = 6^2 - 1^2$, $45 = 7^2 - 2^2$...55...65... which provides an easy prime number test. So, the primes are not random after all. How could anything about numbers be "random". (Received May 23, 2014)

1106-VQ-91 **Ricardo Conceicao***, 100 Hamill st, Oxforg, GA 30054, and **Chris Hall** and **Douglas Ulmer**. *Explicit point on elliptic curves over function fields.*

Let E be the elliptic curve $y^2 = x(x+1)(x+t)$ over the field $\mathbb{F}_p(t)$ where p is an odd prime. In this talk, we discuss the arithmetic of E over extensions $K_d = \mathbb{F}_q(t^{1/d})$ where q is a power of p and d is an integer prime to p. In particular, we present a formula for the rank r_d of $E(K_d)$ given in terms of an elementary property of the subgroup of $(\mathbb{Z}/d\mathbb{Z})^\times$ generated by p. It turns out that r_d is large for many values of d and that for two families of values of d we are able to exhibit explicit points generating a subgroup of $E(K_d)$ of finite index. This talk is based on a joint work with C. Hall and D. Ulmer. (Received July 08, 2014)

1106-VQ-339 **Hieu D Nguyen*** (nguyen@rowan.edu), Department of Mathematics, Rowan University, 201 Mullica Hill Rd., Glassboro, NJ 08028. *A New Proof of the Prouhet-Tarry-Escott Problem.*

The famous Prouhet-Tarry-Escott problem seeks collections of mutually disjoint sets of non-negative integers having equal sums of like powers. In this talk we present a new proof of the solution to this problem by deriving a generalization of the product generating function formula for the classical Prouhet-Thue-Morse sequence. (Received August 23, 2014)

1106-VQ-476 **Patricia Baggett*** (baggett@nmsu.edu), Department of Mathematical Sciences, MSC 3MB P.O. Box 30001, New Mexico State University, Las Cruces, NM 8800380001, and **Andrzej Ehrenfeucht** (andrzej.ehrenfeucht@colorado.edu), Computer Science Department, University of Colorado, Boulder, CO 80309-0430. *Mathematical properties of decimal counting boards.*

A decimal counting board is a rectangular array in which each location has a numerical value. Values in columns and rows are positive rational numbers that form geometric progressions with quotients two and five. (The first rectangular counting board in which rows and columns were geometric progressions was described by John Napier in his Rabdology, published in 1617.) Such boards can be used to introduce positive and negative finite decimals and operations on them in elementary grades. Basic mathematical properties of the boards and some examples of arithmetic algorithms executed on them will be presented. Some open problems in the complexity of algorithms and Diophantine equations concerning such boards will be discussed. (Received August 29, 2014)

1106-VQ-675 **Jasmine Powell*** (jasminepowell2015@u.northwestern.edu), **Andrew Best**, **Patrick Dynes**, **Steven Miller** and **Benjamin Weiss**. *The Emergence of 4-cycles Over Extended Integers.*

Given a ring R and a polynomial f in $R[x]$, an n-cycle is a sequence of n elements of the ring, $(x_1, \ldots, x_n)$, such that $f(x_1) = x_2, f(x_2) = x_3, \ldots, f(x_n) = x_1$. If we consider polynomials in $\mathbb{Z}[x]$, we can quickly see that long cycles are hard to find. In fact, it turns out that over the integers, the only possible cycle lengths are 1 and 2. However, adjoining elements of the form $1/p$ with p prime to our ring of integers is known to sometimes introduce 4-cycles. To determine whether adjoining certain sets of prime reciprocals will introduce 4-cycles, we analyze an equivalent problem: namely, when do four products of primes sum to 0 (each of the four summands may be taken with a positive or negative sign)? Combinatorial techniques allow us to derive conditions on sets of primes that either do or do not admit 4-cycles. We additionally use a numerical approach to investigate the distribution of the sets of primes that admit 4-cycles and examine patterns that emerge. (Received September 04, 2014)

1106-VQ-787 **Ji Young Choi*** (jychoi@ship.edu), 1871 Old Main Dr, Shippensburg, PA 17257. *Ternary Representation of Collatz function.*

The Collatz conjecture is that every positive integer reaches 1, when we apply Collatz function indefinitely, where Collatz function is $f(n) = 3n+1$ if n is odd and $\frac{n}{2}$ if n is even. This talk will present how Collatz function works with ternary numbers, and discuss the Collatz sequences beginning with 3^n and $\sum 3^n$. (Received September 06, 2014)

1106-VQ-1176 **Jean-Francois Biasse*** (jbiasse@uwaterloo.ca), University of Waterloo, 200 University Ave. West, Waterloo, Ontario N2L 3G1, Canada. *Class group and unit group computation in large degree number fields and applications.*

We present a subexponential time method for computing the class group and the unit group of a large degree number field, and we discuss some of its direct applications to the resolution of norm equations and to the analysis of the security of certain cryptosystems.

Computing the class group and the unit group of a number field is a fundamental problem in number theory. There are several unproven conjectures on the structure of the class group such as the Cohen-Lenstra heuristics, while the unit group allows to solve some Diophantine equations, including the Pell equation and more general norm equations. Moreover, our method extends to the computation of a generator of a principal ideal, which applies to lattice-based cryptography. Lattice-based cryptosystems currently receive a lot of attention because they are among the very few proposals for homomorphic and quantum-safe encryption schemes.

Prior to our contribution, computing the unit group and the class group in subexponential time was only possible for classes of number fields of fixed degree. We also represent units by a polynomially bounded amount of information. This task, known as the compact representation, was only possible efficiently for classes of fixed degree number fields. (Received September 11, 2014)

1106-VQ-1360 **Nathan G McNew*** (nathan.g.mcnew.gr@dartmouth.edu), Department of Mathematics, 6188 Kemeny Hall, Hanover, NH 03755. *The most popular largest prime divisors.*

Consider the largest prime factor of each of the integers in the interval $[2, x]$ and let $q(x)$ denote the prime number which shows up most often in this list. In addition to investigating the behavior of this function as x tends to infinity, we look at the range of $q(x)$ and see that it misses most of the primes. We conjecture that the set of these "popular primes" is related to other interesting subsets of the prime numbers. (Received September 12, 2014)

1106-VQ-1404 **Rigoberto Florez*** (rflorez1@citadel.edu), 171 Moultrie st, The Citadel, Mathematics Department, Charleston, SC 29409, and **Robinson Higuita** and **Antara Mukherjee**, 171 Moultrie st, The Citadel, Department of Mathematics, Charleston, SC 29409. *Some algebraic and geometric properties of Fibonacci Polynomials in the Hosoya triangle.*

Fibonacci polynomials is a polynomial sequence generated by a second order recurrence relation. The Hosoya triangle polynomial is a triangular arrangement of polynomials similar to Pascal triangle where the entries are product of Fibonacci polynomials. We use this geometric representation of product of polynomials to construct a discrete convolution.

In this talk we discuss how the convolution gives rise to closed formulas for the alternating sum of products of polynomials such as Fibonacci polynomials, Chebyshev polynomials, Morgan-Voyce polynomials, and other familiar sequences of polynomials. (Received September 12, 2014)

1106-VQ-1636 **Jason I Preszler*** (jpreszler@pugetsound.edu), University of Puget Sound, Dept. of Math and Computer Science, 1500 N Warner, CMB 1043, Tacoma, WA 98416. *An Infinite Family of Cubic Polynomials with Emergent Reducibility at Depth 1.*

A polynomial has emergent reducibility at depth $n \geq 1$ if the polynomial is irreducible and $n-1$ self-compositions are also irreducible, but the n^{th} self-composition is reducible. We will discuss progress made in the study of this phenomena and its relation to arboreal Galois representations and arithmetic dynamics, culminating in an explicitly parameterized family of irreducible cubics whose self-compositions are reducible. (Received September 14, 2014)

1106-VQ-1822 **David W Farmer** and **Sally Koutsoliotas*** (s.koutsoliotas@bucknell.edu), Bucknell University, Lewisburg, PA 17837, and **Stefan Lemurell**. *Finding L-functions of hyperelliptic curves.*

We describe a procedure for finding the Hasse-Weil L-function of a hyperelliptic curve without knowing anything about the curve except its conductor. We illustrate the method with several examples. (Received September 15, 2014)

1106-VQ-1962 **Frank Patane***, frankpatane@ufl.edu, and **A. Berkovich**. *Essentially Unique Representations by Certain Ternary Quadratic Forms.*

In this talk we generalize the idea of "essentially unique" representations by ternary quadratic forms. We employ the Siegel formula, along with the complete classification of imaginary quadratic fields of class number less than or equal to 8, to deduce the set of integers which are represented in essentially one way by a given form which is alone in its genus. We consider a variety of forms which illustrate how this method applies to any of the 794 ternary quadratic forms which are alone in their genus. As a consequence, we resolve some conjectures of Kaplansky regarding unique representation by the forms $x^2 + y^2 + 3z^2$, $x^2 + 3y^2 + 3z^2$, and $x^2 + 2y^2 + 3z^2$. (Received September 15, 2014)

1106-VQ-2078 **Thomas A Hulse*** (hulse@mast.queensu.ca). *Sign Changes of Fourier Coefficients of Half-Integral Weight Cusp Forms.* Preliminary report.

The author is able to demonstrate that given a particular half-integral weight cusp form with real Fourier coefficients, the coefficients on the square-free integers change sign infinitely often. More specifically, it is shown that this is the case when the form is an element of a subspace of new forms which is characterized by the Shimura correspondence. Expanding on the results of a 2011 paper co-authored with E.M. Kıral, C.I. Kuan and L. Lim, and making use of a 2013 sign-changing axiomatization theorem due to J. Meher and M. Ram Murty, this expanded argument hinges on a better understanding of the Rankin-Selberg L-function for averages of cusp forms shifted by additive character as well as when orthogonality of automorphic forms is preserved by this averaging. (Received September 15, 2014)

1106-VQ-2115 **Anil B Venkatesh*** (anilbv@math.duke.edu). *Massey Products of Eisenstein Series and Relations on Multiple Zeta Values.*

We study the connections between modular forms and multiple zeta values. Multiple zeta values (MZV) generalize the values of the Riemann zeta function on positive integers. There are many algebraic relations on the MZV, some of which are induced by modular forms (Pollack 2009). Brown discovered (2014) that twice-iterated Eisenstein series explain Pollack's relations, modulo cubic terms. In this paper, we construct the Massey triple product for Eisenstein series and use this to extend Brown's result to the cubic terms in Pollack's relations. (Received September 15, 2014)

1106-VQ-2117 **Joshua E Hill*** (hillje@uci.edu). *On Calculating the Cardinality of the Value Set of a Polynomial.*

We prove a combinatorial identity that relates the size of the value set of a map with the sizes of various iterated fiber products by this map. This identity is then used as the basis for several algorithms that calculate the size of the value set of a polynomial for a broad class of algebraic spaces, most generally an algorithm to calculate the size of the value set of a suitably well-behaved morphism between "nice" affine varieties defined over a finite field. These algorithms specialize to the case of calculating the size of the value set of a polynomial, viewed as a map between finite fields. These algorithms operate in deterministic polynomial time for fixed input polynomials (thus a fixed number of variables and polynomial degree), so long as the characteristic of the field grows suitably slowly as compared to the other parameters.

These value set cardinality calculation algorithms extend to amortized cost algorithms that offer dramatic computational complexity advantages, when the computational cost is amortized over all the results produced.

The last of these amortized algorithms partially answers a conjecture of Wan, as it operates in time that is polynomial in $\log q$ per value set cardinality calculated. (Received September 15, 2014)

1106-VQ-2161 **Andrew Best**, **Karen Huan** (klh1@williams.edu), **Nathan McNew**, **Steven J. Miller**, **Jasmine Powell**, **Kimsy Tor*** (ktor.student@manhattan.edu) and **Madeleine Weinstein**. *Ramsey Theory Over Imaginary Quadratic Number Fields.*

Optimal bounds in Ramsey theory usually require the construction of the largest sets not possessing a given property. One problem which has been investigated by many concerns the construction of the largest possible subset of $\{1, 2, \ldots, n\}$ (as $n \to \infty$) that are free of 3-term geometric progressions. Building on the significant recent progress in constructing such large sets, we consider higher dimensional analogues.

Specifically, let $\mathbb{Z}[i] = \{a + ib, a, b \in \mathbb{Z}\}$ (with $i = \sqrt{-1}$) be the Gaussian integers. We derive sets of Gaussian integers that avoid 3-term geometric progressions by utilizing the relationship between norms and powers of primes in the norms' factorization. Motivated by Rankin's canonical greedy set over the integers, we construct a set of Gaussian integers avoiding Gaussian integer ratios in a similar fashion, and compute its density using Euler products and the Riemann zeta function. We also establish upper and lower bounds on the maximum upper density of such sets. Finally, we discuss our extensions to other quadratic number fields, and the dependence of the density on the structure of the number field (in particular, on the norm and class number). (Received September 16, 2014)

1106-VQ-2164 **Xixi Edelsbrunner*** (xe1@williams.edu), **Stephan Garcia**, **Kimsy Tor**, **Karl Winsor** and **Steven J Miller**. *Toward Combinatorial Proofs of the Sato-Tate Law and The Weil Bound For Kloosterman Sums.* Preliminary report.

We discuss progress toward elementary combinatorial proofs of the Sato-Tate law and the Weil bound for Kloosterman sums. We apply the classical moment method for probability distributions and the theory of polynomial Legendre sums to a family of matrices due to Fleming, Garcia and Karaali, whose eigenvalues are Kloosterman sums. Using interlacing arguments, we construct combinatorially tractable matrices whose eigenvalues closely approximate Kloosterman sums. By adapting a method of Bose and Sen for studying the eigenvalue distributions of structured random matrix ensembles, we can isolate the main terms of the moments of our eigenvalue distributions, which agree with those of the semicircle distribution. Our approach toward the Sato-Tate law and the Weil bound reduces to a bound on certain Legendre sums which can be related to families of elliptic curves. (Received September 15, 2014)

1106-VQ-2168 **Blake Mackall**, **Steven J Miller**, **Christina Rapti** and **Karl Winsor*** (krlwnsr@umich.edu). *Lower-order biases in elliptic curve Fourier coefficients.* Preliminary report.

Let $\mathcal{E} : y^2 = x^3 + A(T)x + B(T)$ be a nontrivial one-parameter family of elliptic curves over $\mathbb{Q}(T)$, with $A(T), B(T) \in \mathbb{Z}(T)$, and consider the kth moments $A_{k,\mathcal{E}}(p) := \sum_{t \bmod p} a_{\mathcal{E}_t}(p)^k$ of the Fourier coefficients $a_{\mathcal{E}_t}(p) := p + 1 - |\mathcal{E}_t(\mathbb{F}_p)|$. Rosen and Silverman proved a conjecture of Nagao relating the first moment $A_{1,\mathcal{E}}(p)$ to the rank of the family over $\mathbb{Q}(T)$, and Michel proved the second moment is $A_{2,\mathcal{E}}(p) = p^2 + O\left(p^{3/2}\right)$. Cohomological arguments show the lower order terms are of sizes $p^{3/2}$, p, $p^{1/2}$, and 1. In every case we are able to analyze, the largest lower order term that does not average to zero is on average negative. We prove this "bias conjecture" for several large classes of families, including families with rank, complex multiplication, and unusual distributions of signs. We identify all lower order terms in large classes of families, shedding light on the objects controlling these terms. The negative bias in these terms has implications toward the excess rank conjecture and the behavior of zeros near the central point of elliptic curve L-functions. (Received September 15, 2014)

1106-VQ-2351 **Alexa Eryn Ortiz*** (alexa.e.ortiz@gmail.com), Austin, TX 78704. *Rank-Unimodality of b-ary Partitions.* Preliminary report.

This research project focuses on $b-ary$ partitions, denoted $R_b(n)$, which are ways of writing an integer as a sum of powers of b. Previous research has shown that with a suitable partial ordering, the set of binary partitions, denoted $R_2(n)$, is rank-unimodal for $n < 30$, which means that the number of partitions at each level increases, and then decreases, as one moves through the partially ordered set, or poset. Using Maple 17 software, we examined values of n, up to $n = 27,000$, for which $R_2(n)$ is not rank-unimodal. There are only 33 such even n for $n < 27,000$, with values between 30 and 264. We examined the relative location of the rank with the greatest number of elements, which always occurs in the latter half of the poset, and increases for larger n. The next phase of this research is the examination of other properties of the 33 even integers for which $R_2(n)$ is not rank-unimodal, as well as that of those for which $R_2(n)$ is rank-unimodal. Upon examining ternary partitions, denoted $R_3(n)$, we found 369 values of n, up to $n = 30,000$, for which $R_3(n)$ is not rank-unimodal. These values range from $n = 132$ to $n = 3462$. Current research includes expansion of data for $n > 30,000$ for $R_2(n)$ and $R_3(n)$, and $R_b(n)$ for $b > 3$. (Received September 16, 2014)

1106-VQ-2482 **Donald J McGinn*** (djmcginn3@yahoo.com). *Generalized Markoff Equations and Chebyshev Polynomials.*

The Markoff equation is $x^2 + y^2 + z^2 = 3xyz$, and all of the positive integer solutions of this equation occur on one tree generated from $(1, 1, 1)$, which is called the Markoff tree. In this talk, we consider trees of solutions to equations of the form $x^2 + y^2 + z^2 = xyz + A$. We say a tree of solutions satisfies the unicity condition if the maximum element of an ordered triple in the tree uniquely determines the other two. The unicity conjecture says that the Markoff tree satisifies the unicity condition. In this talk, we outline a proof that there exists a sequence of real numbers $\{c_n\}$ such that the tree generated by $(1, c_n, c_n)$ satisfies the unicity condition for all n, and that these trees converge to the Markoff tree. We accomplish this by recasting solutions as linear combinations of Chebyshev polynomials and showing that all of these polynomials are distinct. (Received September 16, 2014)

1106-VQ-2483 **Loren James Anderson***, loren.james.anderson@ndsu.edu, and **Peter D Johnson**. *Hypergraphs on the Integers.*

In 2003, it was conjectured that for any two sets A and B of integers, each of the size 3, there is a 2 coloring of the integers such that no translate of A nor of B in the integers is monochromatic with respect to this coloring. However, in 2010, Balazs Gosztonyi produced a counterexample. During this talk, we make progress toward finding all possible counterexamples. Our strategies include finding colorings that eliminate counterexamples as well as showing how to construct counterexamples from previously known counterexamples. (Received September 16, 2014)

1106-VQ-2490 **Bernd Sing*** (bernd.sing@cavehill.uwi.edu), Department of Mathematics, The University of the West Indies, Cave Hill, P.O. Box 64, Bridgetown, St Michael BB11000, Barbados. *Visibility of Rectangles within the Integer Lattice Points.* Preliminary report.

We say that two distinct integer lattice points P and Q of $\mathbb{Z}^2$ are *mutually visible* if there are no other integer lattice points on the line segment joining P and Q. E.g., the origin $P = (0, 0)$ and any point $Q = (a, b)$ with $\gcd(a, b) = 1$ are mutually visible.

We denote the $r \times s$ rectangle of integer lattice points by $\Delta_{r\times s}$, and investigate the following question: What is the smallest possible cardinality of a set A of integer lattice points not belonging to $\Delta_{r\times s}$, such that each $P \in \Delta_{r\times s}$ is mutually visible by at least one of the lattice points in A?

This question was considered in [1]. We report on the progress achieved so far.

[1] J.D. Laison and M. Schick, "Seeing Dots: Visibility of Lattice Points", *Mathematics Magazine* **80**(4): 274–282 (2007).

(Received September 16, 2014)

1106-VQ-2592 **Ilene H Morgan*** (imorgan@mst.edu) and **Rita SahaRay** (rita@isical.ac.in). *Critical sets in equiorthogonal frequency squares.*

In this paper, we study critical sets in pairs of equiorthogonal frequency squares. Using this stronger definition of orthogonality, a pair of equiorthogonal frequency squares is classified into one of three classes depending on the isomorphism or orthogonality of the corresponding rows and columns. We provide a general theorem determining the size of the critical set of a pair of equiorthogonal squares in which the corresponding rows and columns are isomorphic. For the other possible combinations of corresponding rows and columns, we make a few general observations with a detailed investigation into the conditions for the existence of an equiorthogonal mate and the size of a critical set for a pair of squares of order 8 based on 2 symbols. (Received September 16, 2014)

1106-VQ-2599 **Robert Erra***, 14/16 Rue Voltaire, 94276 Kremlin Bicetre Cedex, France. *An algorithm to solve the Erdös-Strauss equation.* Preliminary report.

The Erd{̈o}s-Strauss conjecture states: for all integers $n > 1$, $4/n$ have an Egyptian Fraction Development (EFD) of length at most 3, i.e. for all integers $n > 1$ the Erd{̈o}s-Strauss equation, has a solution: $\frac{p}{q} = \frac{1}{x_1} + \frac{1}{x_2} + \frac{1}{x_3}$. This conjecture isn't proven but a result by Mordell states that the conjecture is true for all n except possibly the Mordell primes. We propose here an algorithm that is a Las-Vegas algorithm, i.e. it can fail but when it finds a solution, the solution is correct. The algorithm we propose is very simple, we just need an algorithm that gives an EFD: compute the EFD of $\frac{4i}{q}$ from i=1 till a solution of length 3 is found and divide the solution by i. Despite its simplicity, this algorithm gives very interesting results with the Bezoutian algorithm:

- For all experiments it has always found a solution;
- It can be quite fast but with some rare pathological cases.
- All integers i that gives a solution verify $(i/q) = -1$.

(Received September 16, 2014)

1106-VQ-2655 **Mits Kobayashi*** (mkobayashi@csupomona.edu), Department of Mathematics and Statistics, Cal Pol Pomona, 3801 West Temple Avenue, Pomona, CA 91768. *A generalization of a series for the density of abundant numbers.* Preliminary report.

We call a number abundant if the sum of the proper divisors of the number exceeds the number itself. In 1933, Davenport proved that the set of abundant numbers has a natural density. Since then, several improvements have been made to determine upper and lower bounds for this density. A recent result uses the multiplicative function $\sigma(n)/n$ to express the density as a series which can be used to find a lower bound for the density. We present how this result can be generalized to a large class of multiplicative functions. (Received September 16, 2014)

1106-VQ-2665 **Shyam S. Narayanan*** (shyam.s.narayanan@gmail.com), 8209 W 143rd Ter, Overland Park, KS 66223. *Improving the Speed and Accuracy of the Miller-Rabin Primality Test.* Preliminary report.

Currently, even the fastest deterministic primality tests run too slowly, with the Agrawal-Kayal-Saxena (AKS) primality test runtime $\tilde{O}(\log^6(n))$, and probabilistic primality tests are still highly inaccurate. In this paper, we discuss the accuracy of the Miller-Rabin Primality Test and the number of non-witnesses for a general composite odd integer n. We also extend the Miller-Rabin Theorem by determining when the number of non-witnesses $N(n)$ equals $\frac{\varphi(n)}{4}$ and by proving that for all n, if $N(n) > \frac{5}{32} \cdot \varphi(n)$ then n must be of one of the following 3 forms: $n = (2x+1)(4x+1)$, where x is an integer, $n = (2x+1)(6x+1)$, where x is an integer, n is a Carmichael number of the form pqr, where p, q, r are distinct primes congruent to 3 (mod 4). Finally, we find witnesses to certain forms of composite numbers with high rates of nonwitnesses. This work is expected to result in a faster and better primality test for large integers. (Received September 16, 2014)

1106-VQ-2675 **Andrew Best**, **Patrick Dynes**, **Xixi Edelsbrunner**, **Brian McDonald*** (bcmdon11@u.rochester.edu), **Steven J. Miller**, **Kimsy Tor**, **Caroline Turnage-Butterbaugh** and **Madeleine Weinstein**. *Benfordness of Zeckendorf Decomposition.*

Zeckendorf showed that every positive integer can be decomposed uniquely into a sum of non-consecutive Fibonacci numbers. Additionally, the Fibonacci numbers are known to satisfy Benford's law of digit bias, which means that the density of elements with first digit d is $\log_{10}(1 + \frac{1}{d})$. According to this law, the smaller the digit, the more likely it is to occur as a leading digit. Thus the number 1 occurs as a leading digit about 30% of the time, while the number 9 occurs about 4.5% of the time.

We prove that for a randomly selected integer between 1 and the nth Fibonacci number, as $n \to \infty$ the leading digits of the Fibonacci summands in its Zeckendorf decomposition are arbitrarily close to Benford almost surely. The proof proceeds by first analyzing random subsets of Fibonacci numbers for Benfordness. The main ingredient there is showing sets of density are preserved under this process. Using this, we solve our stated problem by proving a correspondence between Zeckendorf decompositions and random subsets of Fibonacci numbers. In those sets the Fibonacci numbers are chosen with a probability $p = 1/\varphi^2$ (where φ is the golden mean) if the previous Fibonacci number wasn't chosen, and 0 otherwise. (Received September 16, 2014)

1106-VQ-2782 **Patrick J Dynes*** (pdynes@clemson.edu), 110 Cherry Hill Avenue, Goose Creek, SC 29445, and **Brian McDonald** (bmcdon11@u.rochester.edu), **Christina Rapti** (cr9060@bard.edu) and **Steven J Miller** (sjm1@williams.edu). *On a Variant of the Lang-Trotter Conjecture Involving Binomial Elliptic Curve Coefficients.*

Abstract: Let E be an elliptic curve $y^2 = x^3 + ax + b$ with $a, b \in \mathbb{Z}$. On average, we expect $\#E_p \approx p$ with $\#E_p$ the number of solutions $(x, y) \in \mathbb{Z}/p\mathbb{Z}$ to $y^2 \equiv x^3 + ax + b \bmod p$. The fluctuations $a_E(p) = p - \#E_p$ about this expected value bounded in absolute value by $2\sqrt{p}$, and thus $a_E(p) \in (-2\sqrt{p}, 2\sqrt{p})$.

In 1976, Lang and Trotter conjectured an asymptotic formula for $\pi_{E,r}(x)$, the number of primes p up to x for which $a_E(p) = r$ for any fixed r. While this question is well beyond current methods, in 2006, James and Yu developed an asymptotic formula for the density of traces of Frobenius that are kth powers. Their analysis uses Hardy-Littlewood estimates for sums of generating functions of pure powers. A natural extension of their work is to examine polynomials that are not pure k-th powers. For example, we prove how often $a_E(p)$ lies in a given arithmetic progression, or is a triangular number. Doing so requires a delicate analysis of new generating functions on the minor arcs in order to obtain sufficient cancellation; these results are of independent interest for other problems in number theory. (Received September 16, 2014)

1106-VQ-2787 **Jason Allen Green*** (jgreen3@worcester.edu). *Fibonacci-like Sequences and Solving ODEs.* Preliminary report.

Certain recursive sequences, like the Fibonacci numbers and the Lucas numbers, are part of a much larger family of recursive sequences. We consider this family of "Fibonacci-like" sequences and discover that some important identities of the Fibonacci numbers can be generalized also, like Binet's Formula, Catalan's Identity, and so on. Moreover, these sequences are closely linked to certain ODEs and the derivatives of their solutions. (Received September 16, 2014)

1106-VQ-2832 **Ron Taylor*** (rtaylor@berry.edu), Department of Math & CS, Berry College, Mount Berry, GA 30149, and **Eric McDowell** (emcdowell@berry.edu) and **Jill Cochran** (jcochran@berry.edu). *Roots of polynomials with generalized Fibonacci number coefficients.* Preliminary report.

In this presentation we construct sequences of polynomials whose coefficients are generalized Fibonacci numbers. These generalized Fibonacci numbers arise from the two-term recurrence $s_n = as_{n-1} + bs_{n-2}$ for arbitrary integers a and b with $s_0 = 0$ and $s_1 = 1$. These sequences have properties similar to the classical Fibonacci numbers including a relationship between the integers a and b, and the limiting value of ratios of consecutive terms of the sequence, which we call $\varphi_{(a,b)}$. The sequences of polynomials arise from considering powers of the $\varphi_{(a,b)}$ and we show that each sequence of polynomials has a subsequence whose roots converge to $\varphi_{(a,b)}$. (Received September 16, 2014)

1106-VQ-2889 **Gregory V. Bard*** (bardg@uwstout.edu), Dept. of Math., Stat., and Comp. Sci., Jarvis Hall Science Wing, University of Wisconsin—Stout, Menomonie, WI 54751. *Computing the Least Factorial that Multiplies a Rational Number into an Integer.*

Given a rational number q, can one compute the smallest possible n such that $n!q$ is an integer? This seemingly simple question is deeper than it sounds, and suggests several cute tangential lemmas. The author suggests an algorithm for solving this problem based on rewriting the denominator of q in base 2, base 3, base 5, base 7, and so forth, up to a certain limit.

The algorithm touches on questions which frequently come up in undergraduate mathematics competitions, such as how many trailing zeroes are found in 2014!, etc... In any case, the talk is meant to be suitable for undergraduates, and only assumes knowledge of modular arithmetic. (Received September 17, 2014)

1106-VQ-2944 **Nicolas David Meyer*** (ndmeyer1888@comcast.net), 2300 S. Illinois Ave. Apt. C4, Carbondale, IL 62903, and **Andrew G. Earnest** (aearnest@siu.edu), 1245 Lincoln Dr. Mail Stop 4408, Carbondale, IL 62901. *Determination of Quadratic Lattices by Local Structure and Sublattices of Codimension One.*

For totally definite quadratic lattices over the ring of integers of a totally real algebraic number field, it is shown that lattices are determined up to isometry by their local structure and sublattices of codimension one. In particular, a theorem of Yoshiyuki Kitaoka for positive definite $\mathbb{Z}$-lattices is generalized to lattices over totally real algebraic number fields. (Received September 17, 2014)

General Session on Research in Topology

1106-VR-38 **Mohammed N. Murad*** (muradkakaee@yahoo.com), University of Sulaimani faculty of Science, School of Science, Mathematics Department, Sulaimani, Sulaimani 00964, Iraq. *Topologically Beta-Type Transitive Maps.*

In this paper, we define and introduce a new type of topological transitive map called topological β–Type transitive map and investigate some of its properties. Further, we introduce the notions of β-minimal mapping. We have proved that every topological β-type transitive map is a topological transitive map as every open set is β-open set but the converse not necessarily true, and that every β-type minimal map is a minimal map as every open set is β-open set, but the converse not necessarily true. (Received May 14, 2014)

1106-VR-271 **Nicholas A Scoville*** (nscoville@ursinus.edu), Ursinus College, Math and CS, 601 E. Main Street, Collegeville, PA 19426, and **Dominic Klyve**. *Discrete Morse theory at the service of elementary number theory.* Preliminary report.

Discrete Morse theory is a tool used to study many questions in topology and combinatorics. A discrete Morse function on a simplicial complex K can be thought of as a blueprint for building K in stages. Part of the information given by the blueprint is the homological sequence which keeps track of how the topology changes at each step of the construction. In this talk, we utilize discrete Morse theory to explore the interaction between discrete Morse functions defined in terms of elementary operations such as sums, products, and least common multiples. We study the resulting homological sequence and its connections to elementary number theory function. (Received August 18, 2014)

1106-VR-438 **James Dabbs** (jamesdabbs@gmail.com) and **Austin Mohr*** (amohr@nebrwesleyan.edu). *Introducing π-Base: An Interactive Encyclopedia of Topological Spaces.*

Is every first countable, separable space also second countable? π-Base currently produces twelve topological spaces that contradict this seemingly plausible claim. Standing on the shoulders of Lynn Arthur Steen and J. Arthur Seebach, Jr.'s superb text *Counterexamples in Topology*, π-Base offers users powerful search, automated deduction, and collaboratively-edited proof. The purpose of this presentation is to demonstrate the features of the website and reflect upon how it can enrich your course in general topology. Even if you cannot attend, we hope you will sign up for a free account at http://topology.jdabbs.com to see how you and your students can learn from and contribute to the project. (Received August 28, 2014)

1106-VR-490 **Thomas J. Osler*** (osler@rowan.edu), Mathematics Department, Rowan University, Glassboro, NJ 08028. *A product of nested radicals for the AGM.*

The Arithmetic-Geometric mean of two positive numbers a and b (AGM(a,b)) is the common limit of two sequences generated by an iterative process. This has proven to be an important device for calculating numbers and function in recent years. In this paper we derive an infinite product representation for this AGM. The factors of this product are nested raticals resembling Vieta's famous product for pi. As an application, we develop approximate expressions for the period of a non linear pendulum. (Received August 30, 2014)

1106-VR-519 **Ramanjit K. Sahi*** (sahir@apsu.edu) and **Noureen A. Khan**. *Ascending Number of Virtual Link Diagrams.*

We define Ascending number $a_v(D)$ of virtual link diagrams D as the minimum number of different crossings that are needed to change the link diagram to a monotone diagram over all based ordered oriented diagrams. We show that

$$a_v(D) \leq C(D) - W(D),$$

where $C(D)$ is the number of crossing of D and $W(D)$ is the warping degree of D. Furthermore, the equality holds if D is a balanced diagram. The relationship is illustrated by sequence of examples. (Received September 01, 2014)

1106-VR-1190 **Weam M. Al-Tameemi*** (weam.altameemi@tamiu.edu), 5201 University Blvd., LBV 312, Laredo, TX 78041, and **Robert R. Kallman** (kallman@unt.edu), Denton, TX 76203. *The Natural Semidirect product $R^n \rtimes G(n)$ is an Algebraically Determined Polish Group.*

Let G be a Polish group. G is algebraically determined Polish group if given any Polish group L and an algebraic isomorphism $\varphi : L \mapsto G$, then φ is a topological isomorphism. Let N and H be two Polish groups and let $\theta : H \to Aut(N)$ be a group homomorphism that satisfies $N \times H \to N$, $(n,h) \to \theta_h(n)$ is continuous. Then $N \rtimes_\theta H$ is a Polish group in the product topology. Let L be a Polish group and let $\varphi : L \to N \rtimes_\theta H$ be a group isomorphism. If $\varphi^{-1}(N)$ and $\varphi^{-1}(H)$ are both analytic subgroups of L, then both $\varphi^{-1}(N)$ and $\varphi^{-1}(H)$ are closed subgroups of L. Next, if $\varphi|_{\varphi^{-1}(N)} : \varphi^{-1}(N) \to N$ is measurable with respect to $BP(\varphi^{-1}(N))$, then $\varphi|_{\varphi^{-1}(N)}$ is a topological isomorphism. Furthermore, if, in addition, θ is injective, then $\varphi|_{\varphi^{-1}(H)} : \varphi^{-1}(H) \to H$ is a topological isomorphism. Finally, under all of these conditions, $\varphi : L \to N \rtimes_\theta H$ is a topological isomorphism and thus $N \rtimes_\theta H$ is an algebraically determined Polish group. Now we will apply the above theorem on the natural semidirect product $R^n \rtimes G(n)$. (Received September 11, 2014)

1106-VR-1712 **Rostam Sabeti*** (rsabeti@olivetcollege.edu), Mathematics and Computer Science Department, 320 S. Main Street, Olivet College, Olivet, MI 49076. *An Algebraic Structure on Cubical Sets.* Preliminary report.

Let $P = I_1 \times \cdots \times I_d \subset \mathbb{R}^d$ be an elementary cube with $\dim(P) = k$. In this talk, we define lower hull and in turn the maximal lower hull of P. For each cube P and $0 \leq i \leq k$, we construct a set of monomials $\mathcal{M}(\mathcal{K}_i(P))$ and an ideal I_i generated by this set. For any admissible monomial order, if $G_i = G(I_i)$ is the reduced Gröbner basis of I_i, then G_i is generated by those generators of I_i that are associated with the elementary cubes and constitute the maximal i-lower hull of P. (Received September 16, 2014)

1106-VR-1883 **Steven Clontz*** (steven.clontz@gmail.com). *Proximal compact spaces are Corson compact.*

J. Bell defined a topological space X to be proximal if X has a compatible uniformity with respect to which the first player has a winning strategy in a certain ω-length game. As noted by P.J. Nyikos, it follows easily from Bell's results that Corson compact spaces are proximal. This talk will cover a joint result by Gary Gruenhage and the presenter proving that a compact space is proximal if and only if it is Corson compact. (Received September 15, 2014)

1106-VR-1921 **Wiktor Jerzy Mogilski*** (mogilski@uwm.edu), 185 E Fairmount Ave, Milwaukee, WI 53217. *The Weighted L^2-(co)homology of Coxeter Groups.*

A recurring theme in geometric group theory is studying the algebraic properties of a group by studying a space on which the group acts on. Associated to a Coxeter group W, there is a particular contractible simplicial complex Σ called the Davis complex on which W acts properly and cocompactly by reflections. Given a positive real multiparameter $\mathbf{q}$, one can define the weighted L^2-(co)homology groups of Σ and associate to them a nonnegative real number called the weighted L^2-Betti number. This equivariant homology theory can be thought of as an elegant geometric interpretation of the growth series of the Coxeter group, and it is closely tied to several other topics such as the Singer conjecture. I plan to briefly outline some of these connections, and discuss my contributions to this topic. (Received September 15, 2014)

1106-VR-2191 **Katherine P. Walsh*** (k3walsh@math.arizona.edu). *Patterns in a Non-Symmetric Polynomial related to the Colored Jones Polynomial of Amphichiral Knots.* Preliminary report.

Much work has been done looking at the patterns in the coefficients of the colored Jones polynomials which are a sequence of Laurent polynomials assigned to each knot. Since the colored Jones polynomial of an amphichiral knot is symmetric in q and $1/q$, we can define a new polynomial $M_{N,K}(x)$ so that $M_{N,K}(q+1/q)$ is the N colored Jones polynomial of the knot K. In this talk, we look at the patterns in the coefficients of this new polynomial, which are much more striking than the patterns in the coefficients of the colored Jones polynomial. We will investigate which of these patterns are potentially related to geometric properties of the knot and which are consequences of the Chebyshev polynomials used to find $M_{N,K}(x)$ from the corresponding colored Jones polynomial. (Received September 16, 2014)

1106-VR-2287 **Jason Marshall Lucas*** (lucas11@math.purdue.edu), Purdue University, Department of Mathematics, 150 N. University Street, West Lafayette, IN 47906. *Models for Configuration Spaces and their Relations.*

Classically, configuration spaces have been of great interest. A basic example is the configuration space of n points in the plane. Such spaces arise naturally in many contexts. If one thickens the points being considered to discs, one is quickly lead to a composition of configurations via insertion. This type of insertion operation is a prime example of the general structure of an operad. The particular operad at hand is called the little discs and is important in the study of loop spaces, and more recently in Deligne's Conjecture and deformation quantization.

The model of little discs is not unique however, and there are other models that are homotopic to it. On one hand these other models may serve the same purpose, but on the other hand due to their structure they are better suited for certain applications. A general operad of this type is called an E_2-operad and its generalizations to thickened points in k dimensions an E_k-operad.

We will review the general setup and establish new relations between certain E_k-operads. (Received September 16, 2014)

1106-VR-2514 **Deborah Vicinsky*** (vicinsky@uoregon.edu). *Goodwillie calculus in the category of small categories.*

Goodwillie calculus, also known as the calculus of functors, is a method of approximating a functor $F:\mathcal{C}\to\mathcal{D}$ between two well-behaved model categories by more homotopically friendly functors similar to how one uses Taylor series to approximate functions by polynomial functions. The category of small categories, denoted $\mathcal{C}at$, has small categories as objects and functors as morphisms. I will show that the derivatives of the identity functor on $\mathcal{C}at$ are zero, i.e. the zero object in the category of spectra on $\mathcal{C}at$. This example is analogous to the example $f(x)=e^{-1/x^2}$ for $x\neq 0$ and $f(0)=0$ in regular calculus. That is, the derivatives of the identity functor exist for all objects of $\mathcal{C}at$, but the Taylor tower only converges to the value of the functor at the zero object. (Received September 16, 2014)

1106-VR-2729 **Mehmet Emin Aktas*** (maktas@math.fsu.edu), 208 Love BuildingMap 1017 Academic Way, Tallahassee, FL 32306, and **Eriko Hironaka**. *Topology of the Complement of Certain Families of Trigonal Curves and Their Associated Dessins d'Enfants.*

I am reporting an on-going work concerning the topology of the complement of trigonal curves in the form $(y-p_1)(y-p_2)(y-p_3)=0$ where $p_1, p_2, p_3 \in \mathbb{R}[x]$ and their associated Dessins d'Enfants. We improved a method to find braid monodromies of that type trigonal curves and by using Burau representations of braid groups, we could compute the Alexander polynomial of these curve complements. Also, we tried to classify the Dessin d'enfants of these curves and are still trying to compute the Alexander like invariants, such as the Alexander polynomial, other invariants based on representations of the braid group, etc. of a these types of trigonal curves in terms of their dessins.
(Received September 16, 2014)

General Session on Teaching or Learning Advanced Mathematics

1106-VS-153 **Ronald M. Brzenk*** (brzenkr@hartwick.edu). *Teaching Mathematical Modeling - What WORKS, What Does NOT.*

This paper will describe topics covered, projects assigned, and interactive pedagogies incorporated in a course in Mathematical Modeling that the author has taught during the past 35 years. Unsuccessful components ("things" that did not work) will also be discussed as well as a variety of assessment techniques. (Received July 30, 2014)

1106-VS-997 **Tetsuya Yamamoto*** (yama3@ou.edu), yama3@ou.edu. *Analysis of Student's Proofs in Light of the Structure of Proof Construction.*

This report explores sources of students' difficulties with proving and provides pedagogical suggestions to help students with proving. The target population was undergraduate students enrolled in undergraduate analysis, algebra, and topology in a large research university. There were a total of 81 proofs collected from students' mid-term, final exams, and in-class problem solving sessions. Those proofs were analyzed in light of the structure of proof construction. The structure of proof construction is a model of proof construction, which provides a comprehensive view that can encompass the aspects, factors, patterns, and features involved in cognitive processes in proof construction across mathematical subjects. The model was useful in explaining sources of students' difficulties with proving and indicated that each mistake or impasse might be caused by more than one factor. The analysis of the students' proofs revealed how students' difficulties might occur and what might hinder them from properly advancing a reasoning process. The findings led to the hypothesis that the knowledge of the structure of proof construction may serve as methodological and metacognitive knowledge to help students with proving. (Received September 16, 2014)

1106-VS-1118 **Matt Boelkins*** (boelkinm@gvsu.edu), C2508 Mackinac Hall, Grand Valley State University, Allendale, MI 49428. *Points-free grading in an intro-to-proof course.*

In Ken Bain's book, "What the Best College Teachers Do," he makes an observation about grades and points: many of the exemplary instructors he studied don't pretend to use points as a way to determine grades. Instead, they are honest with their students that grades represent their "best professional judgment" of a student's performance and work.

I recently sought to implement a version of this approach in a way that was tied to mastery-based grading. Through this talk, I will report on my experience with awarding only marks of Exemplary, Mastered, Progressing, Started, and Insufficient in several different aspects of an intro-to-proofs class, together with an explanation of how I communicated this approach to students and how I ultimately converted their work to letter grades. Student feedback and outcomes will also be shared. (Received September 10, 2014)

1106-VS-1589 **Heather Molle*** (molleh@lakeland.edu). *A Game Theory Course in 14 Days.*

Does your school offer a January or May term? Are you at a loss as to what sort of math class you could teach during such a short semester? Last May, I taught a Game Theory course over just 14 days. In this talk I will discuss the structure of the class, student reactions, and how the class might be modified in the future.
(Received September 14, 2014)

1106-VS-2177 **Regina D Aragon*** (regina.aragon@enmu.edu), ENMU, Station 18, Portales, NM 88130. *The Evolution of an Introduction to Proofs Course, Its Beginning, Present, and Future.* Preliminary report.

At 9:00 am on Thursday, January 16, 2003, in an MAA General Contributed Paper Session, entitled *A new twist on a proofs course*, an audience member boldly stated, "Use How to Read and Do Proofs by Daniel Solow. Your students will be able to write proofs." She guaranteed it. This remark eventually led to positive changes in the introduction to proofs course at Eastern New Mexico University.

This presentation is about the evolution of the introduction to proofs course at Eastern New Mexico University from 1995 to 2014. It will include examples of how the evolution of the introduction to proofs course has affected students' ability to write proofs in abstract algebra and real analysis; assessment results; insights into students' problems with proofs that have become evident as the course has evolved; and plans for future investigations to improve students' ability to read and write proofs. (Received September 16, 2014)

1106-VS-2510 **Rebecca L. Jayne*** (rjayne@hsc.edu), Box 187, Hampden-Sydney, VA 23943. *A Hybrid IBL/Traditional Abstract Algebra Class.* Preliminary report.

After teaching a traditional abstract algebra course and an IBL introductory proofs course, I decided to teach an abstract algebra course with components of IBL and lecture. Each day, students presented problems that lead to discussion and then I lectured and/or had students work in groups. I will discuss how I graded the different components in this class, share some group activities, and give pros and cons of structuring the course this way. (Received September 16, 2014)

1106-VS-2593 **Ali S Shaqlaih*** (ali.shaqlaih@untdallas.edu), Ali Shaqlaih, Department of Math and Informatiom Sciences, 7400 University Hills Blvd, Dallas, TX 75241. *Teaching Approaches of College Geometry for Pre-service High School Teachers.*

College geometry is a fundamental course in teachers' preparation programs. However, topics introduced in such course vary by institution. In this talk, I will present how this course was taught, in five different semesters; by three different approaches including the inquiry based learning approach. Course content a long with the assessment methods in each approach will be discussed. A quantitative analysis of the students' assessment and a qualitative analysis of Students' perceptions will be presented. (Received September 16, 2014)

1106-VS-2773 **Scott M. LaLonde*** (slalonde@uttyler.edu), Department of Mathematics, University of Texas at Tyler, 3900 University Boulevard, Tyler, TX 75799. *Projects in an Introductory Abstract Algebra Course.* Preliminary report.

When teaching any mathematics course, I try to instill an appreciation for the material in my students through applications and historical anecdotes. Faced with my first abstract algebra course, I decided to turn this responsibility over to my students. They completed semester-long research projects on applications, history, or special topics, culminating with a presentation in front of the class. I will discuss the structure of the assignment, the projects that each group completed, and the students' comments. Having done this a second time one year later, I will also compare my two experiences and discuss possible improvements. (Received September 16, 2014)

1106-VS-2779 **Philip P. Mummert*** (mummert@butler.edu), Butler University, Dept. of Mathematics & Actuarial Science, 4600 Sunset Ave, Indianapolis, IN 46208. *Partial Credit for Partial Proofs?*

There are several pitfalls to avoid when creating exams that ask students to write proofs: difficulty in assigning partial credit to incomplete answers, lack of clarity about what may be assumed, and the possibility of completely overwhelming students unsure of where to start. I will share my own positive experiences with exam "prooflets" from a junior-level introductory analysis course. (Received September 16, 2014)

General Session on Teaching or Learning Calculus

1106-VT-317 **John W. Thompson*** (jwt01@pitt.edu), 141 Krebs Hall, U. of Pittsburgh at Johnstown, 450 Schoolhouse Road, Johnstown, PA 15904, and **Stephen Curran**. *Calculus with and without Top Hat.* Preliminary report.

In the fall 2014 semester we ran two sections of a traditional Calculus I class utilizing the student response program Top Hat and two sections without. We plan to briefly describe how we implemented the program, including examples with an explanation of the context, to relate interesting stories of the experience, and to present a synopsis as to whether the extra work is worth it. (Received August 21, 2014)

1106-VT-346 **Kimberly S. Sofronas*** (sofronki@emmanuel.edu), 400 The Fenway, Boston, MA 02115, and **Thomas C. DeFranco**, **Hariharan Swaminathan**, **Nicholas Gorgievski** and **Charles Vinsonhaler**. *A Study of Calculus Instructors' Perceptions of Approximation as a Unifying Thread of the First-Year Calculus.*

This paper discusses findings from a research study designed to investigate calculus instructors' perceptions of approximation as a central concept and possible unifying thread of the first-year calculus. The study also examines the role approximation plays in participants' self-reported instructional practices. A survey was developed and then administered to a stratified random sample of 3,930 mathematicians at higher education institutions throughout the United States. Quantitative and qualitative methods were used to analyze the data gathered. While 89% of participants reported that they do view approximation as important to student understanding of the first-year calculus, significantly fewer are translating that view into an instructional approach that presents approximation as a central concept (51%) or unifying thread (40%). Four primary reasons for this incongruity are discussed. The findings from this research provide a baseline for what is known about the perceptions and teaching practices of calculus instructors regarding the role of approximation in first-year calculus courses. Research-based findings related to the role of approximation ideas in the first-year calculus could have implications for first-year calculus curricula. (Received August 24, 2014)

1106-VT-398 **Rebecca Dibbs*** (rebecca.dibbs@tamuc.edu). *"How does this help me?" Modeling growth in introductory calculus by using participation in formative assessment.* Preliminary report.

One of the challenges of teaching introductory calculus is the large variance in student backgrounds. Formative assessment can be used to target which students need help, but little is known about why formative assessment is effective with adult learners. The purpose of this study was to investigate the effect of participation in formative assessment on achievement in an introductory calculus course. Fifty-four introductory calculus students participated in the study, 23 of whom were regularly participating in formative assessment. Students' ACT Math scores, gender, native language, participation in formative assessment, and scores on the three major calculus labs throughout the semester were collected. In the growth model analysis, participation in formative assessment reduced more unexplained variance than any other factor. (Received August 26, 2014)

1106-VT-1308 **Lake Ritter*** (lritter@spsu.edu), SPSU: Department of Mathematics, 1100 S. Marietta Pkwy, Marietta, GA 30060. *Teaching Calculus II in modular format to increase student success.* Preliminary report.

Calculus II can serve as a significant gateway course for science and engineering programs. Unfortunately, it's frequently a course in which weakness in mathematical foundation can derail student progress towards a degree. In this talk, we present a modular course structure being tested at Southern Polytechnic State University in Calculus II. The principal characteristic of the course structure is frequent assessment with ongoing opportunity for students to participate in revision activities. The revision activities serve the critical function of keeping students from falling behind. But it may help to increase student confidence and to allay grade related fear without sacrificing academic standards. The course to be discussed is a traditional, four credit hour, face-to-face course with revision using an online learning management system. The basic structure can easily be adapted to online or hybrid courses as well as for use in other college mathematics classes. (Received September 12, 2014)

1106-VT-1379 **Susan Marla Orme*** (ormes@byui.edu), **Heidi Jean Turner** and **Elaine Rumsey Wagner**. *Student Use of Example Generation in a Calculus Course: Potential Barriers to Student Learning with Example Generation.*

Mathematicians routinely use the skill of self-generation of examples to test and verify mathematical principles, theorems, and concepts, and yet the processes through which undergraduates learn to productively generate examples are not well understood. Students in multiple first-semester calculus courses participated in a teaching experiment designed to develop the mathematical skill of example generation and productive use of these examples to learn novel mathematical concepts. Through three iterations, a hypothetical learning trajectory was tested and refined to align with the actual learning observed in students. The findings showed that students participating in the teaching experiment became more self-directed, productive, and skillful example generators when learning novel mathematical concepts. The study provided evidence that the use of example generation is a plausible teaching method for introducing novel mathematical concepts in a first-semester calculus course. This presentation provides details of the findings about potential barriers students face in the implementation of example generation in a first-semester calculus. (Received September 16, 2014)

1106-VT-1381 **Heidi Jean Turner*** (turnerh@byui.edu), **Elaine Rumsey Wagner** and **Susan Marla Orme**. *Student Use of Example Generation in a Calculus Course: Student Success in Learning with Example Generation.*

Mathematicians routinely use the skill of self-generation of examples to test and verify mathematical principles, theorems, and concepts, and yet the processes through which undergraduates learn to productively generate examples are not well understood. Students in multiple first-semester calculus courses participated in a teaching experiment designed to develop the mathematical skill of example generation and productive use of these examples to learn novel mathematical concepts. Through three iterations, a hypothetical learning trajectory was tested and refined to align with the actual learning observed in students. The findings showed that students participating in the teaching experiment became more self-directed, productive, and skillful example generators when learning novel mathematical concepts. The study provided evidence that the use of example generation is a plausible teaching method for introducing novel mathematical concepts in a first-semester calculus course. This presentation provides details of the findings about student success in learning novel mathematical concepts using example generation in a first-semester calculus course. (Received September 16, 2014)

1106-VT-1559 **Philip Joseph Lombardo*** (plombardo@sjcny.edu). *GeoGebra 5.0 and Multivariable Calculus.* Preliminary report.

GeoGebra 5.0 is a free program that will graph surfaces and vector-valued functions in $\mathbb{R}^3$. In this talk, I share some of the visualizations that I created in GeoGebra 5.0 to teach critical topics in multivariable calculus. The program does not have heavy system requirements, it's freely available to students, and fairly easy to learn. (Received September 14, 2014)

1106-VT-1771 **Paul Sisson*** (paul.sisson@lsus.edu), Louisiana State University in Shreveport, One University Place, Shreveport, LA 71115, and **Tibor Szarvas** (tibor.szarvas@lsus.edu), Louisiana State University in Shreveport, One University Place, Shreveport, LA 71115. *Enneper Surfaces – An Example of History and Exploration in the Teaching of Calculus.*

Calculus is still too often presented as a collection of tools and theorems devoid of human connections and relationships to other topics. This tendency is understandable, given the sheer amount of material many departments try to cram into their calculus sequence, but learning usually suffers as a result. Drs. Sisson and Szarvas, both of whom have many years of experience as professors of mathematics and as university administrators, show how Enneper surfaces present the opportunity to incorporate history and exploration in the teaching of calculus. This approach allows students to learn calculus by making connections with what they already know and what they can discover through the use of technology and each other. (Received September 15, 2014)

1106-VT-2169 **Jason Samuels*** (jsamuels@bmcc.cuny.edu), **Aaron Wangberg**, **Brian Fisher** and **Eric Weber**. *An Innovative, Three-Dimensional Approach to Multivariable Calculus Instruction.* Preliminary report.

Multivariable Calculus presents a unique challenge for both instructors and students, as the objects of study can no longer be properly represented on a flat page. We have designed and implemented an innovative curriculum for Calculus III in which students use plastic surfaces, measurement tools, and group activities in order to explore and uncover many of the key ideas and formulas of multivariable calculus. In this talk we will give an overview of the course, demonstrate how students discover the gradient vector and its properties, and share some initial results from students and instructors. This research is part of the project Raising Calculus to the Surface, funded by the National Science Foundation DUE #1246094. (Received September 16, 2014)

1106-VT-2182 **Joel M Kilty*** (joel.kilty@centre.edu), Centre College, 600 W. Walnut Street, Danville, KY 40422. *Blending Mathematical Modeling and Calculus: A Data Driven Approach to Calculus.* Preliminary report.

In the modern world we are inundated with data. As mathematicians, we are typically more comfortable discussing the behavior of functions presented analytically, in contrast with data-driven or tabular presentations. In this talk, I present a data driven approach to Calculus for students who will only take one mathematics course in college. The course is designed to develop the student's ability to model data with elementary functions and then improve their models using the Method of Least Squares. The tools of Calculus are used to analyze these models in both the discrete and continuous contexts. The software package R, with the *mosaic* package, enables the success of this approach, including the analysis of "real" data sets. (Received September 16, 2014)

1106-VT-2377 **Therese Shelton*** (shelton@southwestern.edu), 1001 E. University Ave., Georgetown, TX 78626, and **Alison M Marr** (marra@southwestern.edu). *Working to Improve Student Success in Calculus I Through Pre-calculus Support.* Preliminary report.

We developed and implemented a method to assess preparation for Calculus I, improve retention and success rates in Calculus I, and help students to choose an alternate course in a timely fashion, if needed. This preliminary report will discuss the Moodle learning management site we created that contains an online pre-calculus assessment exam, pre-calculus review videos, and practice worksheets. We will discuss the successes and failures of our project thus far, including some preliminary data analysis and a description of the administration required. We invite suggestions and ideas as we continue to seek improvements for our methods. Initial funding was provided by the Associated Colleges of the South, and we will share our materials fully with the other ACS schools. (Received September 16, 2014)

1106-VT-2379 **Yuliya Melnikova*** (yuliyamelnikova@gmail.com). *Alignment in Students, Teaching Assistants, and Instructors on the Purpose and Practice of Calculus I Labs.* Preliminary report.

Currently, political and economic demand for students graduating with Science Technology Engineering and Mathematics (STEM) degrees is high, but unfortunately, a large percentage of students switch to non-STEM majors in the first year of study. Roadblock courses, such as Calculus I, can contribute to poor retention rates due to classroom environment and instructor practices. Research suggests recitation sessions (or labs) led by teaching assistants (TAs) can positively impact student retention rates.

This study investigates the role of labs in Calculus I instruction. Through surveys, classroom observations, and TA interviews, the researcher investigated how the lab portion of a Calculus I course is viewed by its participants (which include the instructor, the TA, and students) and how those views align between the participants and the practices in the lab. Furthermore, the study explored how the alignment or misalignment of views and practices affect student opinions of STEM study. Preliminary findings on the alignment of participant views and classroom practices will be presented, and implications for increasing student retention rates will be discussed. (Received September 16, 2014)

1106-VT-2448 **Ryan Grover*** (ryan.grover@colorado.edu). *"I Used to Hate Math. Now I Hate it Even More!" Undergraduate Calculus I Students' Perceptions of Mathematics: A Look at Survey Responses.*

This study looked at various first-semester calculus courses intended for different student populations (e.g., biology majors and business majors) taught at a large university. Students enrolled in these Calculus I courses were asked to complete pre and post surveys on their perceptions and understanding of mathematics. Differences in student responses were then analyzed as a whole and through gender and other demographics and compared between the various calculus courses and to national data. Of particular interest is how students' views change over the semester, especially towards the constructs that make up the surveys: personal interest, real world connections, problem solving confidence, sense making, and conceptual understanding. Survey items and results will be shared. Notable analysis includes large differences in male and female shifts in problem solving confidence in Business Calculus, suggesting that women were much more likely to self-report a decrease in their confidence in solving problems.

By analyzing how student perceptions towards mathematics change, both within these constructs and as a whole, over time, we can begin to understand their motivation to learn mathematics and how our courses may impact those changes. (Received September 16, 2014)

1106-VT-2698 **Caroline J. Hagen*** (caroline.hagen@tufts.edu). *Students' Knowledge of Functions and Their Learning of Key Calculus Concepts.*

The transition into university-level mathematics is a critical juncture in the education of future science, technology, engineering, and mathematics (STEM) professionals. As student retention in STEM fields remains far too low, there is a need to improve student learning outcomes in the courses that often push students out of STEM fields, particularly introductory calculus. Research shows that even high-performing calculus students often demonstrate weak understandings of key calculus concepts that are necessary in future math, science, and engineering courses. Thus, more work needs to be done on how to foster more robust learning in undergraduate calculus. In addition, research has shown that strong understandings of basic notions about mathematical functions support many kinds of mathematics learning. To date, not enough is known about students' knowledge of functions and how this may influence their learning of key introductory calculus concepts. This talk helps address this research gap by presenting results of a study of undergraduate calculus students' ideas about functions and how this interacts with their understandings of basic calculus concepts such as limit and rate of change, and the implications this may have on the teaching of calculus at the undergraduate level. (Received September 16, 2014)

1106-VT-2871 **Joel Louwsma*** (jlouwsma@smith.edu), Department of Mathematics and Statistics, Smith College, Northampton, MA 01063. *Inverting multivariable calculus.*

I will describe my experience inverting a medium-sized multivariable calculus course at the University of Oklahoma. Students read sections of the textbook in preparation for class, and much of the class time was spent working on activities in groups. Class sessions were held in a technology-enhanced active learning classroom. I will describe the logistics of how this course was set up and discuss some of the advantages and challenges of teaching in this way. (Received September 16, 2014)

General Session on Teaching or Learning Developmental Mathematics

1106-VU-279 **Wayne D Russell*** (wrusse01@aol.com), 782 East 39th Street, Brooklyn, NY 11210. *Social Media - a Supplemental Instructional Platform to promote Dynamic Self-Regulated Learning: Deconstructing mathematical precepts through virtual social constructivism lenses.*

The objective of this research is to determine the effectiveness of using a Social-Media Supplemental Instructional Platform (SSIP) to promote Dynamic Self-Regulated Learning (SRL-d) in developmental college mathematics students. This research contends that virtual interactions can adequately stimulate students' enthusiasm, passion, insight, interest and curiosity - all of which are primary tenets of SRL-d. The research argues that a virtual platform can serve as an immediate space to aid in the contextualization of mathematical concepts which invariably leads to higher order mathematical elaborations. Our Findings indicate that there is a significant improvement in participants' attitude toward learning mathematics, and there was a 20% increase in class average as well as 25% increase in performance when compared with the general population. (Received August 19, 2014)

1106-VU-572 **Qingxia Li*** (qli@fisk.edu), 411 Annex Ave, Apt B4, Nashville, TN 37209. *Teaching Developmental Mathematics Courses at HBCUs.* Preliminary report.

This research project is supported by NSF Implementation Award(HRD-1332284) at Fisk University. Fisk University is a historically black university and ranks "#1 in Liberal Arts HBCU in research". One of the objectives of this award is to shorten the completion time for math prerequisites and improve mastery of math skills. In Fall 2014, we did a pilot study to assess gains in math content and changes in students' attitude towards mathematics by comparing traditional teaching with teaching with case studies. In this presentation, I will first discuss about the success and challenges in teaching developmental mathematics courses at Fisk University. Then I will demonstrate the changes in math content and attitude towards mathematics collected from the pilot study of 125 students in Intermediate Algebra at Fisk University. (Received September 08, 2014)

1106-VU-1045 **Shumei C Richman*** (richmansmc@gmail.com). *Teaching Beginning Algebra Beyond Visual Forms.* Preliminary report.

In my ten plus years of teaching beginning algebra in colleges, I have been searching for the root causes and remedies for many common mistakes made by my students. One of the most common mistakes is the misuse of the distributive law, a(b+c)=ab+ac, which many students see as a visual form without operations involved. Therefore, for example, they simplify the statement 3(1/3*x) mistakenly to 3x. To help students avoid these visual-form-led mistakes, I have tried different approaches in my teaching, but most of them are too complicated; only a few are simple enough to be effective and well accepted by my students. The most effective one is twin comparison, in which two or more problems with almost exactly the same visual form are organized side-by-side in a problem set, such as Ex 1.(a) Solve 3(1/3+x)=12, (b) Solve 3(1/3 *x)=12; or Ex 2.(a) Simplify x/2*3/4, (b) Solve x/2=3/4. In this talk, we will discuss how visual forms may lead to mistakes, through several examples in beginning algebra, from linear equations to rational expressions. We will also discuss how some approaches help students see the hidden math concepts beyond visual forms, as well as the impacts of these approaches on students' math learning in general, besides avoiding mistakes. (Received September 14, 2014)

1106-VU-1050 **Jennifer Kosiak*** (jkosiak@uwlax.edu), **Bob Hoar** (rhoar@uwlax.edu), **Jim Sobota** (jsobota@uwlax.edu) and **Robert Allen** (rallen@uwlax.edu). *FastTrack Summer Math Program: Supporting Developmental Math Students.*

The increase in the number of students who are placed in developmental mathematics is a national concern. The FastTrack Summer Math Program is a bridge program for incoming freshmen that have been placed into developmental mathematics at the University of Wisconsin-La Crosse. Students in this program spend 6 weeks online in a MOOC (Massive Open Online Course) environment and then have the option to participate in a one-week face-to-face workshop prior to the start of the semester. The goal of these activities is to further develop their mathematical skills in order to move ahead in their mathematics placement. This session will provide an overview of this program and discuss three years of research related to the project including student success in retaking a placement exam, subsequent grades in a college credit mathematics course, and retention rates within the university. This session will also examine the replication of the FastTrack Program across several universities. (Received September 10, 2014)

1106-VU-1159 **Alvina J Atkinson*** (aatkinso@ggc.edu), 1000 University Center Lane, School of Science & Technology, Lawrenceville, GA 30043, and **Barry D. Biddlecomb** and **D. Natasha Brewley**. *Fostering Student Success in Developmental Math.*

In 2007, a unique opportunity occurred that allowed a learning support mathematics program to be built from scratch incorporating small class sizes, mastery learning, self-paced learning, and just-in-time teaching. In light of efforts to redesign and accelerate learning support courses, how has the design fared over the past seven years? In this presentation, the presenters will describe the design and implementation of a technology-based, mastery-based, self-paced developmental mathematics course created in 2007 at the presenters' institution. The presenters show data from the lifetime of the program including success rates within the course itself and in subsequent mathematics courses. (Received September 11, 2014)

1106-VU-1656 **Mary H Williams*** (s-mwilli34@math.unl.edu), 215 Henzlik Hall, Lincoln, NE 68505, and **Ruth Heaton** and **Wendy Smith**. *Understanding One Faculty Member's Experience Teaching College Algebra.* Preliminary report.

For large Universities, teaching College Algebra is largely delegated to graduate teaching assistants(GTAs), while decisions about College Algebra curricula and logistics tend to be made by faculty. Such faculty typically do not teach College Algebra regularly and may not be familiar with the student demographics in these lower-level courses. While this arrangement is logical in many ways, it creates a disparity between the intended and the enacted curriculum of the course. For one Midwestern University, which is trying to change the pedagogy and success rates of freshman-level mathematics classes, one senior faculty member decided to teach a section of College Algebra. The purpose of this narrative research study was to capture this professor's experiences teaching College Algebra, to more deeply understand how this experience might affect the professor's teaching and gather feedback that could improve future teaching lower level courses. Implications of this research include helping other large Universities consider (a) what faculty might need to know in order to better develop College Algebra curricula and effective teaching strategies; (b) how similar experiences can impact the teaching practices of tenured faculty; and (c) how to better prepare GTAs to teach College Algebra. (Received September 14, 2014)

1106-VU-1815 **Hansun To** (hto1@worcester.edu), 486 Chandler Street, Math Department, Worcester, MA 01602, and **Eileen Perez*** (eperez2@worcester.edu), 486 Chandler Street, Worcester, MA 01602. *Embedding Remedial Mathematics in Liberal Arts Quantitative Reasoning Course.* Preliminary report.

In order to reduce the time spent in remediation for students and increase their graduation rates the course was redesigned. The redesign of this mathematics course focused on embedding the remedial material using a just in time approach. An additional credit hour was added to support the remediation. The course design and pilot results will be discussed. (Received September 15, 2014)

1106-VU-2136 **Jeff Bay** and **Maria Siopsis***, 502 East Lamar Alexander Parkway, Maryville, TN 37803. *Get ready: A competency-based path to avoiding the developmental mathematics course using Khan Academy.* Preliminary report.

While developmental mathematics courses are often required of students before they are allowed to enroll in college-level mathematics or science courses many students complain that the material is review of familiar content that is covered at a pace they feel is slower than necessary. From the student perspective, these courses slow down progress towards a major or graduation, often unnecessarily. We describe a competency-based process using Khan Academy and an in-house online placement test that allows students to show readiness for college-level math courses before arriving on campus as first-year students. The approach requires a relatively small amount of college resources, including time and effort on the part of college faculty. Additionally, it may encourage early self-reliance and student responsibility for college success. We present the preliminary results of this process on incoming first year students, including their ability to succeed in a general education introductory statistics course and their retention at the college. (Received September 15, 2014)

1106-VU-2365 **Nihan S. Er*** (`nihaner@akdeniz.edu.tr`), Antalya, Turkey. *Faculty Perspectives on College Readiness and Remedial Courses.*

The purpose of this study is to investigate college mathematics professors' perspectives on college-readiness of freshmen throughout the United States of America. The study also aims to display information on topics that students need to have mastered before entering college. A survey, prepared based on the Common Core State Standards, was disseminated to mathematics faculty in 48 states. The survey instrument included five demographic questions, 38 scaled items with 6 subscales (Basics: Number sense, logic, and set theory, Algebra, Functions, Geometry, Statics and Probability, and Reasoning and Generalization), and five open response items. Data were gathered from 737 mathematics faculty. The descriptive statistics of the data indicates that a majority of mathematics faculty think that the freshmen have poor mathematical ability on important topics of college mathematics. For all of the subscales, the means of abilities for institutions that offer remedial courses were lower than that for the institutions that do not offer such courses. (Received September 16, 2014)

1106-VU-2753 **Umesh P Nagarkatte*** (`umesh@mec.cuny.edu`), Department of Mathematics, A1/L08E, 1638 Bedford Avenue, Brooklyn, NY 11225, and **Joshua Berenbom**. *Abstract: Adapting the Singapore Model Method of Problem Solving Framework to College Level – Progress Report.*

Singapore Mathematics ranks first in the world in the Trends in International Mathematics and Science (TIMSS) studies. We are revamping Prealgebra to College Algebra adapting the Singapore Mathematics Problem Solving Framework. We also involve the Theory of Constraints (TOC) and Thinking Process tools to prepare a logical list of all difficulties in every topic. This can serve as a checklist for mastery of the topic. It also helps to connect to appropriate KhanAcadmy.org videos. The Framework is represented in a pentagon of interrelated components: Concepts, Skills, Processes, Metacognition, and Attitudes. Integrating the five components addresses diverse learning styles and deeper understanding. Great emphasis is placed on the aspect of learning the concepts numerically, graphically, algebraically and analytically. The key feature of the model method is illustrated in rectangular bars which are pictorial representations of the models applicable to both arithmetic and algebra topics helping students learn the mechanics involved in solving word problems. This concrete-pictorial-abstract approach is depicted by the part-whole and comparison models. In elementary and intermediate algebra geometrical interpretations of topics such as factoring deepen students' understanding. (Received September 16, 2014)

1106-VU-2902 **Christina Lee*** (`leec@tcnj.edu`), Department of Mathematics and Statistics, The College of New Jersey, 2000 Pennington Road, Ewing, NJ 08628. *Using Assessment and Management to Improve Learning Outcomes in Precalculus.* Preliminary report.

This talk addresses steps The College of New Jersey (TCNJ) took to tackle the high failure rates and low student preparedness for Calculus in our Precalculus courses. Modular style and multiple-semester style courses were not a logistical option for TCNJ. Many of precalculus sections are taught by adjuncts, therefore to help understand the course dynamics we implemented common homework and a common final to create consistency among all the sections as well as collect learning outcome data. Using this data we made syllabus changes and created a 7 question pretest students took on the first day of classes. We found that student scores on the pretest correlated to course failure rates. Data from the common final and pretest together enable us to advise our students and manage specific learning outcomes semester to semester. (Received September 17, 2014)

General Session on Teaching or Learning Introductory Mathematics

1106-VW-608 **Whitney George*** (`wgeorge@uwlax.edu`), Department of Mathematics, 1725 State St, La Crosse, WI 54601. *Development of a General Education Online Course.*

The development of an online course can seem like a huge project especially for anyone who has little experience with online learning and teaching. I will share my own experiences and give the timeline of events in the development of an online general education course at a medium sized public university. We will talk about the expected and unexpected obstacles that I encountered and reflect on the decisions made through the process. (Received September 03, 2014)

1106-VW-1098 **Andrew R Gainer-Dewar*** (gainerdewar@hws.edu), HWSC Dept. of Math and CS, 300 Pulteney Avenue, Geneva, NY 14456. *Writing and mathematics in a first-year seminar.*

Many liberal-arts colleges offer or require an interdisciplinary first-year seminar. Designing and teaching such a seminar offers a unique opportunity to engage with first-year students outside the calculus classroom and with material far afield from the usual service and major fare. However, some of the institutional requirements, such as that the course be "writing rich", can be extremely intimidating to mathematicians! I'll discuss my experiences running such a course at Carleton College, focusing in particular on some writing assignments I developed and the institutional resources and relationships that allowed this mathematician to extract thoughtful, engaged, and interesting writing from students with a wide variety of interests. (Received September 10, 2014)

1106-VW-2048 **Wendy Hageman Smith*** (smithwh@longwood.edu), Department of Mathematics and Computer Scienc, Longwood Univeristy, 201 High Street, Farmville, VA 23909, and **Becker Sidney Smith**. *Turbo-charging freshman engagement in introductory courses through a 2-lecture motivational seminar on how and why to succeed at college mathematics.*

Freshman don't arrive knowing what math courses they need to achieve their academic and career goals, how the specific courses offered can help them better achieve those goals, or how to optimize their chances of success in the math courses they choose (or are required) to take. Most regrettably, too few freshmen are offered this information. Missed opportunities, poor curriculum choices, and academic failure are the inevitable result. We have combined the authors' research into student attitudes towards mathematics (including math anxiety) with best practices for the teaching and learning of mathematics as promulgated by the NCTM. The result is a brief (2 or 3 lecture) program for integration into "first experience" college math courses that orients their attitudes, expectations, and study habits towards getting the most out of their current—and likely future—coursework in mathematics. This "short-course" in the value of college math, in disarming math anxiety, and in establishing sound student skills enhances student optimism and engagement exactly when they need it most. In addition to serving the needs of the students, math programs benefit from lower failure rates, increased enrollment in additional courses, and a greater likelihood of acquiring new majors and minors. (Received September 15, 2014)

1106-VW-2165 **Maria Siopsis***, 502 East Lamar Alexander Pkwy, Maryville, TN 37803. *Tailgating and trajectories: Using corn hole data to illustrate transformations and characteristics of parabolas.*

We report on the effectiveness of using trajectory data from a corn hole game to present transformations of functions and characteristics of parabolas, common topics in many college algebra and pre-calculus courses. Students use data captured from the trajectory of their own corn hole beanbag to explore these topics in an applied (and personal) context. Beginning with the quadratic function $y = x^2$, students apply transformations in order to find a quadratic function whose graph matches their data. The result is compared to the best-fit quadratic and analyzed for location of the vertex and intercepts. Concepts are then interpreted in the context of the game. (Received September 15, 2014)

1106-VW-2188 **John W. Hoggard*** (jhoggard@edinboro.edu), Dept. of Mathematics and Computer Science, 109 Ross Hall, 220 Scotland Road, Edinboro, PA 16444. *Making a College Algebra Class Accessible to Students with Visual Impairments.*

Students with visual impairments present unique challenges to a college algebra classroom. Mathematical notation is problematic in electronic sources and teaching graphing is highly visual. Inspired by experience with a student in a college algebra class, I will discuss attempts to make handouts and online homework (using WeBWork) accessible to screen readers, adjustments to lectures, some approaches to graphing, and other challenges and solutions. Suggested resources for teachers will be included. (Received September 16, 2014)

1106-VW-2454 **Yu-Ju Kuo*** (yjkuo@iup.edu) and **Rick Adkins**. *Scholarships-Creating Opportunities for Applying Mathematics– DUE 0966206 Project Outcomes Report (2010-2014).*

The Scholarships Creating Opportunities for Applying Mathematics (S-COAM) project at Indiana University of Pennsylvania, while increasing the number of students pursuing mathematics degrees, is unique in its goal of establishing a supportive connection of Master's students with undergraduates through scholarship cohort activities. Over a period of four years, need-based scholarships supported 23 graduate students from the M.S. in Applied Mathematics and 45 undergraduate students seeking a major in a mathematical area or a mathematics minor with another science-related major from biology, chemistry, computer science, geoscience, natural science, or physics. Through this project more students took advanced mathematics courses, enhancing their preparation for the workforce and further studies. In this presentation, we will share best practices and activities engaging and retaining a diverse group of students, outcomes from our program, as well as identify effective strategies based on the literature research and the program assessments. (Received September 16, 2014)

1106-VW-2667 **Mary Beisiegel***, 368 Kidder Hall, Department of Mathematics, Oregon State University, Corvallis, OR 97331. *Can I be the change I want to see? Navigating the ease and obstacles between research ideals and classroom realities.*

At Oregon State University, the College Algebra course has been redesigned so that at least half of classroom time is structured around student engagement in mathematical tasks, rather than on lecture. As part of this effort, instructors and teaching assistants are offered professional development support, with recommendations from the National Research Council, the CRAFTY Report, and recommendations from the CUPM guiding the new type of engagement with students in the course. In my role as a mathematics educator, I support this work by creating and developing professional development modules, engaging in curriculum renewal, along with studying both the instructor, teaching assistant, and student experiences in the redesigned course. After two years of studying the redesign through others' experiences, I changed my role from researcher to instructor for the course in order to more fully understand the expectations, workload, and changes to instruction required by the redesign. I aimed to answer the question: Can I be the change I want to see? In this session, I will share my exploration of my own teaching practice in the context of the redesigned course, as well as the change from researcher to instructor, along with the rewards and obstacles of this work. (Received September 16, 2014)

1106-VW-2709 **Annela R Kelly*** (a3kelly@bridgew.edu). *Games as a Learning Tool in Mathematics.*

Recent research shows that games are an effective way to learn mathematics at elementary school level. My talk will investigate the correlation between college students' success in logic games and their success in mathematics class. I will explore the ways the study improves student learning. (Received September 16, 2014)

1106-VW-2749 **Emma Smith Zbarsky*** (smithzbarskye@wit.edu). *The Effects of Assignment Timing on Student Learning.* Preliminary report.

This talk will describe the preliminary findings of a Fall 2014 research study on teaching calculus. We enrolled four sections of Engineering Calculus I in the study, two as controls and two as experimental groups, with several other sections acting as independent controls. The experimental sections used OpenStaxTutor for online homework using two different schedules. The independent controls used WileyPlus online homework. All other course supports stayed the same. We will discuss the effects of different homework schedules on student learning. (Received September 16, 2014)

1106-VW-2751 **Carolyn E. Luna*** (carolyn.luna@utsa.edu), One UTSA Circle, San Antonio, TX 78249. *The Challenges of Teaching Developmental Mathematics Courses: Making Mathematics Appeal to Disengaged Learners by Seeking Depth Over Breadth.* Preliminary report.

Current curriculum standards for developmental mathematics courses require educators to cover chapters of content ranging from solving rational equations to dividing by complex numbers. Students, who often still struggle with using the addition principle to solve linear equations, suffer with this push for breadth of content over a deeper understanding of the course topics. Educators who teach these classes, however, have many tools at their disposal to enliven their classrooms and make mathematics appealing to struggling students. By actively engaging students in lessons that encourage mathematical discourse and peer interaction, developmental mathematics courses can stimulate higher order thinking that is motivated by the learners themselves. Although the breadth of the course content may be sacrificed for a deeper understanding of more fundamental mathematical topics, students will actually enjoy learning by doing a subject most of them once dreaded. (Received September 16, 2014)

1106-VW-2795 **Chris Oehrlein*** (coehrlein@occc.edu). *Developing and Teaching a Hybrid, Mid-Term College Algebra for Business, Life and Social Science Majors.* Preliminary report.

Many students enrolled in the mid-semester College Algebra sections will be coming out of a College Prep Math course in which they were taught, learned and were assessed through multiple modalities - lecture, collaborative activities, in-class computer exercises and quizzes, paper-and-pencil testing as well as interactive computer testing. The College Algebra sections offered to these students have been fairly traditional in the delivery and assessment of the course objectives. Students asked if if were possible to have a College Algebra option that was similar in style to their College Prep Math experience. A full-time and a part-time professor got together to offer the mid-semester College Algebra in a hybrid format and attempted to make the course resemble the

College Prep Math course while upholding the expected standards of the College Algebra curriculum. (Received September 16, 2014)

General Session on Assorted Topics

1106-VX-124 **Jathan Austin*** (jwaustin@salisbury.edu), Department of Mathematics & Computer Science, Salisbury University, 1101 Camden Avenue, Salisbury, MD 21801. *Generating Pythagorean Triples of a Given Height.* Preliminary report.

The height of a Pythagorean triple is the difference between the hypotenuse of the triple and one of its legs. In this talk, the presenter will show how Pythagorean triples of a given height can be generated using matrices. (Received July 23, 2014)

1106-VX-203 **Jack Bookman*** (bookman@math.duke.edu), Mathematics Department, Duke University, Box 90320, Durham, NC 27708-0320. *Improving the Preparation of Graduate Students to Teach Undergraduate Mathematics.*

The biggest challenge facing new college instructors, is the minimal preparation for teaching they receive in their graduate teaching. In this presentation, a new initiative to address this problem will be discussed. The purpose of this project, funded by NSF under the auspices of the MAA, is to help faculty who wish to start or improve a program to provide professional development (PD) for novice college mathematics instructors. There are informal networks of people who work in this arena but the resources that do exist are inaccessible or difficult to locate for those new to the work. The purpose of the proposed project is to provide better access to these resources and to create durable versions of the existing informal networks. These efforts will create an infrastructure, housed and supported by the Mathematical Association of America (MAA), to enhance the mathematics community's ability to provide teaching-related professional development to graduate students. The project includes the following components: a multimedia suite of resources for PD providers and mechanisms for building it; a professional community of practice bringing together providers and researchers; workshops and webinars for providers and researchers; and distance delivery of PD for graduate students. (Received August 12, 2014)

1106-VX-390 **Chad Scott*** (cscott@uwsuper.edu), 3021 Swenson Hall, University of Wisconsin, Superior, WI 54880. *The Erdős 25 Cent Problem.*

Paul Erdős was well known for offering monetary prizes for finding solutions to problems that vexed him; the larger the dollar figure, the more difficult he found the problem. As a graduate student at a relatively remote school in the middle of the country, I was lucky enough to see him speak and sit with him at dinner. I had puzzled most of the day on some of his problems but got nowhere. At dinner I jokingly asked him, "So, do you have any 25 CENT problems?" He chuckled but right near the end of the dinner he slid a napkin over to me and a friend. I asked what it was and he said, "A 25 cent problem." I'll describe the problem and the solution I found. (Received August 26, 2014)

1106-VX-467 **Shaun V. Ault** (svault@valdosta.edu), Valdosta State University, 1500 N. Patterson St., Department of Math and Computer Science, Valdosta, GA 31698, and **Charles J. Kicey*** (ckicey@valdosta.edu), Valdosta State University, 1500 N. Patterson St., Department of Math and Computer Science, Valdosta, GA 31698. *Counting paths in corridors using circular Pascal arrays.*

A circular Pascal array is a periodization of the familiar Pascal's triangle. Using simple operators defined on periodic sequences, we find a direct relationship between the ranges of the circular Pascal arrays and numbers of certain lattice paths within corridors, which are related to Dyck paths. This link provides new, short proofs of some nontrivial formulas found in the lattice-path literature. This is based on work that has recently been accepted for publication. (Received August 29, 2014)

1106-VX-488 **Raymond N. Greenwell*** (matrng@hofstra.edu), Department of Mathematics, 103 Hofstra University, Hempstead, NY 11549. *A Card Trick Involving Basic Algebra.*

The magician asks a volunteer to shuffle and cut a deck of cards, and then distribute some of the cards into piles that seem to leave a random number of cards in each pile. Then, based on the number of cards in the pile and the values of certain cards, the magician locates a card in the remainder of the deck and predicts its value. Turning the card over verifies the prediction. The trick, based on basic algebra plus a bit of deception, has some similarities to "Luck on the Web" by Colm Mulcahy, as well as a trick published in a UMAP module by Peter Lindstrom. But this trick is particularly dramatic in its effect and has not been previously published. (Received August 30, 2014)

1106-VX-536 **David S. Torain, II*** (`david.torain@hamptonu.edu`). *Structure Theorems for Commutative Noetherian Moore-Penrose Two (MP2) Rings and Elementary Divisor Rings.*

This paper puts forth some original structure theorems for commutative and Noetherian (Moore-Penrose Two) rings as well as unit MP2 rings. An arbitrary ring R will be called MP2 as follows: Given any nonzero element a in R, there exists a nonzero x in R such that xax = x. Also, an arbitrary ring R will be called MP1 (Moore-Penrose One) if it satisfies the following property: Given any nonzero element a in R, there exists a nonzero x in R such that xax = x. Interestingly enough, MP2 rings appear frequently in atmospheric science isothermal curve estimating problems, and in engineering applications for solving unstable linear systems, or in business demand-supply matrix models with ill-conditioned Leontief matrices. (Received September 01, 2014)

1106-VX-564 **Jason J Molitierno*** (`molitiernoj@sacredheart.edu`), Sacred Heart University, Department of Mathematics, 5151 Park Avenue, Fairfield, CT 06825. *Writing Projects in a First Year Seminar Class in Mathematics.*

The First Year Seminar Class in Mathematics, titled "Mathematics without Calculations—It's a Beautiful Thing!" is a class that is meant for non-math majors. The goal of this class is to teach students college level writing and speaking. In this class, I assign daily writing assignments where students must read about a mathematical topic from the textbook (Heart of Mathematics, Burger & Starbird) and write a two-page reflection. Topics that have assigned are the infinitude of prime numbers, comparing different levels of infinity, one-to-one correspondences, platonic solids, four dimensionality, and fractional dimensions. In this talk, I will discuss the specifics of these writing assignments and how they improved student writing. I will also discuss lengthier research papers and presentations assigned. (Received September 02, 2014)

1106-VX-606 **Hossein Behforooz*** (`hbehforooz@utica.edu`), 1600 Burrstone Road, Utica, NY 13502. *Alternate approach to conic sections.*

Classic conic sections are the locus of points based on the distances of certain points from fixed points or lines. By changing these fixed points to conic sections (like circle instead of point) and changing the concept of distance to tangential distance, we obtain few interesting set of new conic section like curves. The interesting properties of these curves will be discussed. (Received September 03, 2014)

1106-VX-650 **Firuz Kamalov*** (`firuz@cud.ac.ae`). *Property T and amenable transformation group C^*-algebras.*

It is well known that a discrete group which is both amenable and has Kazhdan's Property T must be finite. In this talk we generalize the above statement to the case of transformation groups. We show that if G is a discrete amenable group acting on a compact Hausdorff space X, then the transformation group C^*-algebra $C^*(X,G)$ has Property T if and only if both X and G are finite. Our approach does not rely on the use of tracial states on $C^*(X,G)$. (Received September 04, 2014)

1106-VX-681 **Brian G. Kronenthal*** (`kronenthal@kutztown.edu`), Kutztown University, Department of Mathematics, P.O. Box 730, Kutztown, PA 19530, and **Felix Lazebnik**. *When Can You Factor a Quadratic Form?*

Let $\mathbb{F}$ be a field and n a positive integer. A polynomial $Q \in \mathbb{F}[X_1, \ldots, X_n]$ of the form

$$Q = Q(X_1, \ldots, X_n) = \sum_{1 \le i,j \le n} a_{ij} X_i X_j,$$

where $a_{ij} = a_{ji}$ for all i and j, is called a *quadratic form*. The polynomials

$$X_1^2 + X_1X_2$$

and

$$2X_3^2 + 2X_1X_2 - X_1X_3 - 4X_2X_3 - 6X_3X_4 + 3X_1X_4$$

are examples.

Consider the problem of determining, without using a computer or calculator, whether a given quadratic form factors into the product of two linear forms. It is often highly nontrivial to derive a solution by inspection. However, we can take advantage of equivalent conditions, which we will discuss in this talk. Furthermore, we will highlight vocabulary such as "reducible," "degenerate," and "singular" that is used in the literature to describe these conditions, as well as highlight the inconsistency with which this vocabulary is applied. (Received September 04, 2014)

1106-VX-698 **Ricardo E. Rojas*** (ricardo.rojas@northern.edu), 1200 South Jay Street, Aberdeen, SD 57401. *College Algebra Suffices: No Calculator, No Calculus.*

Northern State University's Math 102 (College Algebra) students encounter questions that appear to be unsolvable without either a graphing calculator or a higher form of mathematics (i.e., calculus). Presumably, Math 102 students do not know calculus; thus, they must use a graphing calculator to obtain a decimal approximation of the solution. Sometimes, this decimal approximation does not communicate the complete significance of the solution. In this presentation, I examine three such Math 102 questions. At first glance, they appear to only be solvable with either a calculator or calculus. Nevertheless, I answer all three questions using only the methods of College Algebra. I thus show that a Math 102 student with no knowledge of calculus can answer these questions without a calculator. My research involving the nonstandard yet effective uses of these methods has revealed two insights. First, these methods will sometimes reveal important information about the solution that a calculator will not. Second, these methods will sometimes appeal to students who would prefer to attack these problems without a calculator. (Received September 04, 2014)

1106-VX-739 **Norman Bradley Fox*** (norman.fox@uky.edu) and **Richard Ehrenborg**. *The Descent Set Polynomial Revisited.*

The descent set polynomial $Q_n(t)$, first introduced by Chebikin, Ehrenborg, Pylyavskyy and Readdy, was found to have many factors that are cyclotomic polynomials. The most common factor, $\Phi_2 = t + 1$, exists if the proportion of odd descent set statistics is $1/2$, which occurs if the binary expansion of n has two or three 1's. We continue their work of explaining cyclotomic factors, focusing on a large class of factors of the form Φ_{2p} where p is a prime. We additionally show that if Φ_2 is a factor of $Q_{2n}(t)$ then it is a double factor. Finally, we give conditions for an odd prime power $q = p^r$ for which Φ_{2p}^2 is a double factor of $Q_{2q}(t)$ and of $Q_{q+1}(t)$. (Received September 08, 2014)

1106-VX-777 **Wing Hong Tony Wong*** (wong@kutztown.edu), Department of Mathematics, Kutztown University of Pennsylvania, 15200 Kutztown Road, Kutztown, PA 19530, and **Sin Tsun Edward Fan**. *Constructing matroids with fixed parameters.*

There are three basic parameters for matroids, namely the size (denoted by n), the rank (denoted by r), and the number of bases (denoted by b). If we specifies n, r, and b such that $0 < r \leq n$ and $1 \leq b \leq \binom{n}{r}$, does there exist such a matroid satisfying all three parameters?

Dominic Welsh asked this question during the first Conference on Combinatorial Mathematics and its Application in University of Oxford in 1969, and this question has been wide open since then. In 2008, Mayhew and Royle proved that there is no matroid with size 6, rank 3, and 11 bases, but they conjectured that such a matroid always exists for any other set of parameters (n, r, b).

In our paper, we back up this conjecture with a proof that such a matroid always exists if r is big relative to $n - r$. We also prove that such a matroid exists for $r = 2$ and $r = 3$, except $(n, r, b) = (6, 3, 11)$. (Received September 06, 2014)

1106-VX-1151 **Leah E Vaughan***, 60 South Lincoln Street, Washington, PA 15301, and **Roman Wong**, 60 South Lincoln Street, Washington, PA 15301. *Orbit of the Transformation $T(x, y) = (y + \frac{1}{x}, x + \frac{1}{y})$.*

In this paper, we analyze the orbit of the transformation $T(x, y) = (y + \frac{1}{x}, x + \frac{1}{y})$ from any initial point (x_0, y_0) on the plane except at points on the axes. Different trends are observed depending on the location of the initial point (x_0, y_0). We showed that except for some special points where the orbits become cyclic, all the other orbits are either a line or two lines tending to infinity in different fashions. The observed linear trends extend infinitely with slopes relative to the initial point. We support the analysis by illustrating the orbits graphically from Excel. (Received September 11, 2014)

1106-VX-1230 **Jenna T Nguyen*** (nguyenjt@jay.washjeff.edu), 1483 Barry Drive, North Huntingdon, PA 15642, and **Jerald E Hertzog** and **Savanna R Starko**. *One Step Apart Integers.*

Inspired by the Fibonacci identity $f_{n-1} \times f_{n+1} + 1 = f_n^2$ for odd n, we define a relation $\sim$ on $\mathbb{N}$ by $a \sim b$ if and only if $ab + 1 = k^2$ for some k. $\sim$ is obviously symmetric but not reflexive nor transitive. The relation results in an undirected graph G with vertex set $\mathbb{N}$ and an edge between a and b if $a \sim b$. We investigate the neighbor sets $N(a) = \{x \in \mathbb{N} \mid a \sim x\}$ and the upper bounds for the distance $d(a, x) = \min\{\text{length of paths from } a \text{ to } x\}$ for special $a \in \mathbb{N}$. We also look into triples (a, b, c) with $a \sim b, b \sim c$, and $c \sim a$ and the resulting cycles on the graph. (Received September 11, 2014)

1106-VX-1235 **Maxwell Christopher Chomas*** (chomasmc@jay.washjeff.edu), 60 South Lincoln St., Box 248, Washington, PA 15301, and **Roman Wong** and **Terrence Wong**. *Expected Portion filled by k-Tiles.*

In this paper, we examine the expected portion $E(n)$ in a $1 \times n$ array that will be filled if dominoes are randomly placed in succession. We derive the formula for $E(n)$ and prove that the ratio $\frac{E(n)}{n}$ tends to $1-\frac{1}{e^2}$ when $n \to \infty$. We demonstrate a Java simulation of the experiment with various n and compare the experimental result with the theoretic one. We then extend the experiment to filling the array with k-tiles, $1 \leq k \leq n$, and illustrate the behavior of the function $\frac{E(n,k)}{n}$. (Received September 14, 2014)

1106-VX-1623 **Autumn Dailey** and **Paul M. Wrayno*** (paul.wrayno@cnu.edu). *Broadening Student Groups Through Combinatorial Designs.*

When assigning group work projects over the course of the semester, instructors tend to prefer that either the groups remain fixed or that students work with as many other students as much as possible. Partitioning students into teams over a series of projects without students repeating a teammate can be challenging. In this talk we discuss the history of this problem, notably the Kirkman School Girl problem. We will discuss Kirkman Triple Systems, which can be used to form 3-person teams for each project with each student working together exactly once when the class size is $6k+3$ students. We will explore why this is not possible for class sizes of $6k$ students and present our work on a partial Kirkman Triple System for a class of 36 students to assist a colleague with his lab group schedules. (Received September 14, 2014)

1106-VX-1731 **Tien Chih*** (tien.chih@newberry.edu), 517 Turkey Pointe Lane, Chapun, SC 29036. *Generalizing Cantor-Schroeder-Bernstein: Counterexamples in Standard Settings.*

The Cantor-Schroeder-Bernstein theorem states that any two sets that have injections into each other have the same cardinality, i.e. there is a bijection between them. Another way to phrase this is if two sets A, B have monomorphisms from A to B and B to A, then they are isomorphic in the setting of sets. One naturally wonders if this may be extended to other commonly studied systems of sets with structure and functions which preserve that structure. Given two objects with injective structure preserving maps between them are the structures of these objects the same? In other words, would these two objects be isomorphic in their respective setting? We see that in vector spaces, which are determined completely by their bases sets, this is true. However, when the objects are graphs, groups, rings or topological spaces, one may find counterexamples to such an extension. This is interesting, as it contradicts the naive intuition that two objects which are "subobjects" of each other must be the same. We provide some of these counterexamples. (Received September 15, 2014)

1106-VX-1951 **Mohamed Allali*** (allali@chapman.edu). *Application of Fourier Transform to Image Noise Removal.*

As digital images are shared, cropped, scanned, printed then scanned, digital images can lose vital image information or acquire noise in the form of blurring, salt and pepper, noise patterns, and/or scanner lines. In this talk, I will show how Fourier Transform can be used to fix imperfections on an image and can help reconstruct the image to its original form. This can be incorporated as a solid project into many mathematics courses. (Received September 15, 2014)

1106-VX-2052 **Heather Ames Lewis*** (hlewis5@naz.edu), Nazareth College, 4245 East Avenue, Rochester, NY 14618. *(More) Math Mistakes that Make the News.*

A decimal point is misplaced. A company forgets to use order of operations. An error term is doubled instead of eliminated. This talk will share real-life examples of when relatively minor mathematical errors had newsworthy consequences. (Received September 15, 2014)

1106-VX-2079 **Colm Mulcahy*** (colm@spelman.edu). *The Fitch Cheney Five Card Trick for Three Cards.*

The classic The Fitch Cheney Five Card Trick sees a mathemagician given five random cards from a regular deck, one of which she hides. She shows the other four in a face-up row to an accomplice, who is able to figure out what the hidden one is, using only mathematics. Fifteen years ago, the author modified this to work where given any four cards, three were shown in a row, and the identity of the fourth was correctly deduced by the accomplice. (Some of the displayed cards might be face down there.) Even better, given any three cards, we'll show how it's possible to show all of them in a row, and the accomplice can name one of the face-down cards. (Received September 15, 2014)

1106-VX-2261 **David C Clark*** (clarkdav@gvsu.edu), Department of Mathematics, 1 Campus Drive, Allendale, MI 49401. *Minor errors but a joy to read: Assessing portfolio problems in calculus.*

Portfolio writing assignments are considered a best practice for introducing students to mathematical writing. The assessment method used for portfolios is crucial, since it provides incentives which strongly affect students' decisions.

We describe an assessment system, created specifically for portfolio problems, which makes a useful distinction between "significant" and "minor" errors. This helps focus students' attention on the most important aspects of mathematical writing and gives a sense of scale to feedback. It also separates mathematical issues from writing style and offers useful formative feedback to students. This system is extremely flexible and can be used consistently across many different assignments and woven deeply into a course's structure.

We will describe this system's implementation in two settings: the University of Minnesota Talented Youth in Mathematics Program (UMTYMP, an accelerated calculus sequence for talented high school students), and a first year calculus course populated with scientists and engineers at Grand Valley State University. We will provide advice for integrating the system deeply into a course, give examples of its use, and reflect on its strengths and weaknesses. (Received September 16, 2014)

1106-VX-2263 **David A. Huckaby*** (david.huckaby@angelo.edu). *A Visual Exploration of the Power Method.*

We will proceed through a sequence of Power Method examples that lead students through an exploration of various facets of the method's convergence. For each example, the convergence is illustrated with an animation in MATLAB/MuPAD. The animation in each successive example vividly reveals one or more characteristics of the convergence—some of them surprising—while simultaneously suggesting more questions and prompting further investigation. Through this guided exploration, students gain intuition into how the Power Method works while deepening their understanding of eigenspaces. The exploration can be used as an interactive classroom demo or as a lab assignment. (Received September 16, 2014)

1106-VX-2298 **Juan Mora*** (juan.mora@asu.edu), 6902 W.Sheila Ln, Phoenix, AZ 85033, and **Armando Salinas**. *Basketball Simulation: Applying Data from the 2010 NBA Playoffs.*

Teams are a social structure that can be observed across numerous biological societies. Teams as a social structure can be observed within sports,and in particular Basketball. The 5 positions in basketball are widely recognized and accepted throughout the league, which means no single team deviates from having all 5 positions. This allows for position players to be unbiasedly compared to other position players across the league. Metrics to measure different variable operators were invented to measure the success of the team. Such metrics are discussed in Ambruster's (Basketball Teams as Strategic Networks. Ambruster was able to capture team dynamics through metrics such as degree centrality, clustering, entropy, and flow centrality. In the wake of the paper, Ambruster has a substantial amount of data to be analyzed, such as passes, shots taken, free throw successes,free throw failures, and more. Our task is to create a program that can simulate a basketball game by strictly using the probabilities of what a player will do with the ball at any given time. The program will be relatively successful if it can replicate most of the 2010 NBA playoff games. Implications of our program include evaluating a team member's worth and impact in the game. (Received September 16, 2014)

1106-VX-2453 **Andy Martin***, andrew.martin@kysu.edu. *On the Number of Representations of a Positive Number as a Finite or Infinite Egyptian Fraction.*

Every positive rational number can be represented as an Egyptian Fraction. How many such representations are possible? Every positive real number is the sum of an infinite sub-series of the Harmonic Series (that is, an "Infinite Egyptian Fraction.") How many such representations are possible here? This talks answers these questions. (Received September 16, 2014)

1106-VX-2509 **Belinda Copus** (copus@ucmo.edu), Dept. of Math & CS, Warrensburg, MO 64093, and **Mahmoud Yousef*** (yousef@ucmo.edu), Dept. of Math & CS, Warrensburg, MO 64093. *Computer Science Education: Closing the Hiring Gap.* Preliminary report.

It is widely known that there are not enough Computer Science graduates to fill Computer Science jobs. This paper explores why students are not electing to study Computer Science, even though there is a high demand for the field. An anonymous survey was administered to undergraduate students at a Midwestern university. The survey included a wide range of questions addressing impressions of what computing professionals do, and students' actual computer science educational background (high school and college). Basic demographics were also collected. The study indicated that at least one-third of students do not have an accurate comprehension of what computing science professionals do. The study also shows that exposure to Computer Science in high school often did little to affect students' perceptions of the field. It was shown that females have a stronger tendency to regard computer science as "boring," even when they have taken no computer science courses and have no experience on which to base their opinions. This study examines many correlates from the data and draws conclusions concerning the need to improve computer science education in high school and undergraduate settings, with the ultimate goal of increasing computer science enrollment and meet the hiring demand. (Received September 16, 2014)

1106-VX-2806 **Samantha K Fairchild*** (samantha.fairchild15@houghton.edu), **Rafael Setra** and **Robert Strichartz**. *The abelian sandpile model on fractal graphs.* Preliminary report.

Research concerned with placing grains of sand on a single vertex in the integer lattice and then "toppling" the sandpile according to certain rules is extensively studied in relation to boundary growth and the formation of fractal patterns. Using the fractal patterns as inspiration, we consider graph approximations of postcritically finite fractals including the Sierpinski gasket, the Mitsubishi gasket, the Pentagasket, and the Hexagasket. We share results for asymptotic behavior of the boundary as the number of grains of sand placed on a single vertex increases as well as results and conjectures regarding the patterns of the resulting configurations in relation to the sandpile group. (Received September 16, 2014)

2010 MATHEMATICS SUBJECT CLASSIFICATION

Compiled in the Editorial Offices of MATHEMATICAL REVIEWS and ZENTRALBLATT MATH

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05 Combinatorics
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08 General algebraic systems
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15 Linear and multilinear algebra; matrix theory
16 Associative rings and algebras
17 Nonassociative rings and algebras
18 Category theory; homological algebra
19 *K*-theory
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28 Measure and integration
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43 Abstract harmonic analysis
44 Integral transforms, operational calculus
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58 Global analysis, analysis on manifolds
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78 Optics, electromagnetic theory
80 Classical thermodynamics, heat transfer
81 Quantum theory
82 Statistical mechanics, structure of matter
83 Relativity and gravitational theory
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91 Game theory, economics, social and behavioral sciences
92 Biology and other natural sciences
93 Systems theory; control
94 Information and communication, circuits
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