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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
1096	January 15–18, 2014	Baltimore, MD	EXPIRED	Vol 35, No. 1
1097	March 21–23, 2014	Knoxville, TN	January 28	Vol 35, No. 2
1098	March 29–30, 2014	Baltimore, MD	January 28	Vol 35, No. 2
1099	April 5–6, 2014	Albuquerque, NM	February 11	Vol 35, No. 2
1100	April 11–13, 2014	Lubbock, TX	February 10	Vol 35, No. 2
1101	June 16–19, 2014	Tel Aviv, Israel	TBA	None
1102	September 20–21, 2014	Eau Claire, WI	July 29	Vol 35, No. 3
1103	October 18–19, 2014	Halifax, Canada	August 19	Vol 35, No. 3
1104	October 25–26, 2014	San Francisco, CA	September 3	Vol 35, No. 4
1105	November 8–9, 2014	Greensboro, NC	September 16	Vol 35, No. 4
1106	January 10–13, 2015	San Antonio, TX	TBA	Vol 36, No. 1

BALTIMORE, MD, January 15–18, 2014

Abstracts of the 1096th Meeting.

00 ► General

1096-00-15 **Eitan Grinspun***, Computer Science Department, Columbia University, New York, NY. *Movie magic: The mathematics behind Hollywood's visual effects.*

Blockbuster films have amazing visual effects. Virtual stunt doubles, animated characters, and imaginary creatures are built from mathematical models of hair, fur, skin, and clothing. Explosions, floods, and disasters that would be dangerous if not impossible to film in real life are instead simulated on computers using mathematical models of fracture, fire, granular media, and liquids. This is the world of applied mathematics with an artistic flair. In this talk aimed at the general audience I will expose various aspects of movie magic, and the exciting mathematical questions that arise. (Received April 11, 2013)

1096-00-92 **Sylvia Bozeman** (sbozeman@spelman.edu), Mathematics Department, 350 Spelman Lane, SW, Atlanta, GA 30314, and **Ulrica Wilson*** (uwilson@morehouse.edu), Mathematics Department, 830 Westview Drive, SW, Atlanta, GA 30314. *Enhancing the Achievements of African-American Mathematicians.*

In the culture of mathematics, there are components of success that are often not obvious, but are necessary to navigate effectively through a graduate program and subsequent career in the mathematical sciences. Traditionally African Americans have experienced particular difficulty in accessing the information and introductions that are essential to understanding the unwritten rules and gaining the visibility and exposure to key people in their field. This talk will point to ways of filling such gaps using tested intervention activities. These organized activities have resulted in a broad array of achievements and new leaders in the mathematics community. We will describe some of these activities and the impact of fifteen years of the EDGE (Enhancing Diversity in Graduate Education) Program. (Received July 24, 2013)

1096-00-270 **Ilse Haim** (ihaim@terpmail.umd.edu), **Robert Strichartz** (str@math.cornell.edu) and **Travis Westura*** (tsw52@cornell.edu). *Sandpile Models on Fractal Graphs.* Preliminary report.

The Abelian Sandpile Model involves an initial configuration of chips on a graph $G = (V, E)$. If $x \in V$ has more chips than its degree, then, in a procedure called toppling, one chip is distributed to each neighboring vertex. This process continues until the system reaches a stable configuration in which no more topplings can take place. When using a sufficiently large number of chips on $\mathbb{Z}^2$, the resultant stable configuration has an interesting fractal structure.

We simulate toppling distributions on fractal graphs, emphasizing the Sierpinski Gasket and Carpet. Varying the initial configurations, we characterize numerous patterns in the resulting stable states. This process involves generating complex images of fractal structures, revealing an assortment of patterns not appearing on $\mathbb{Z}^2$.

Also, we examine a model of randomly adding chips to the vertices of a Gasket and stabilizing the system. This process results in a number of recurrent chip configurations that form an abelian group. We investigate this group structure and identify important characteristics of it. Additionally, we discover a relationship between the elements of this group and the configurations that appear when a stack of n chips is placed on one vertex and toppled. (Received August 25, 2013)

1096-00-293 **Mariana Smit Vega Garcia***, msmitveg@math.purdue.edu, and **Nicola Garofalo**. *New monotonicity formulas and the optimal regularity in the Signorini problem with variable coefficients.*

We will start by describing the interior Signorini, or lower-dimensional obstacle problem, for a uniformly elliptic divergence form operator $L = \mathrm{div}(A(x)\nabla)$ with Lipschitz continuous coefficients and discuss the optimal regularity of the solution. Our main result states that, similarly to what happens when $L = \Delta$, the variational solution has the optimal interior regularity $C^{1,\frac{1}{2}}_{loc}(\Omega_\pm \cup \mathcal{M})$, where $\mathcal{M}$ is a codimension one flat manifold which supports the obstacle and divides the domain Ω into two parts, Ω_+ and Ω_-. We achieve this by proving some new monotonicity formulas for an appropriate generalization of the celebrated Almgren's frequency functional. (Received August 26, 2013)

1096-00-512 **Eva Knoll**, **Wendy Landry** and **Tara Taylor*** (`ttaylor@stfx.ca`), Department of Mathematics, Statistics and CS, St. Francis Xavier University, Antigonish, NS B2G 2W5, Canada. *Visualizing Concepts from Modern Algebra Using Variations of Generalized Woven Figure Eights.*

Students often struggle with abstract concepts from modern algebra and typical classes incorporate few ways to make the concepts concrete. Using a set of woven paper artefacts, this talk will present a possible way to visualize concepts (equivalence relations and equivalence classes, modular systems, groups of symmetries...) and making their abstract definitions more concrete. The set of artefacts used to illustrate these concepts are derived from our investigation of open-laced woven mats produced in several cultures in the South Pacific. The exemplars that will be shown present variations of the figure eight, and can be created using readily available materials and straightforward instructions. (Received September 05, 2013)

1096-00-520 **Mary D Shepherd*** (`msheprd@nwmissouri.edu`). *Defining an "Optimal" Cross-Stitching Method.*

This work extends the "use the least amount of thread" work of Barbara Ashton and Kevin Dove to the "preferred" type of stitch on the back of the fabric where all stitches on the back are vertical. In other words, no horizontal stitches on the back are allowed. There is a "double row" idea here—each row now has a direction so there is an even/odd type behavior noted. Some of the regions Ashton and Dove showed were stitchable with the minimum amount of thread are not allowed when only vertical stitches on the back are allowed, but others that were not discussed in their work (they gave necessary but not sufficient conditions) by their method are natural results here. In addition, it is possible to assign a type of measure to the "badness" of non-vertical stitches on the back so that one can discuss optimal stitching patterns for regions other than those that can be stitched with only vertical stitches on the back. Other less traditional cross-stitch patterns will also be discussed. (Received September 05, 2013)

1096-00-767 **Monica Farmer Cox*** (`mfc@purdue.edu`), 701 W. Stadium Ave., ARMS 1329, West Lafayette, IN 47907. *Mathematics: A Foundation for Advancing Research in Graduate Engineering Education.*

This session offers a perspective about how mathematics served a foundation for the speaker's pursuit of graduate degrees in engineering and education. Included will be a presentation of findings across multiple federally-funded projects focused upon the preparation of graduate science, technology, engineering, and mathematics (STEM) students for a variety of careers. The primary focus will be upon a newly-developed assessment tool, the Global Real-time Assessment Tool for Teaching Enhancement (G-RATE), which provides instructors with pedagogical feedback that is collected from direct classroom observations, students' survey responses, and instructors' self-reflections of teaching. The speaker will discuss the evolution of the G-RATE and G-RATE research findings along with efforts to commercialize the G-RATE. Connections to the speaker's mathematics training will be referenced along with lessons learned regarding the crossing of disciplinary boundaries within academia. (Received September 10, 2013)

1096-00-1329 **James R Gatewood*** (james.gatewood@usma.edu). *Two Mode Matrix of Urban Structure.*

We present an urban network that takes into account how streets and neighborhoods interact and influence each other. This two-mode urban structure presents another approach to analyze urban environments. We use GIS to construct a network map of an American city and then apply network analysis to evaluate how the network structure influences such features as traffic flow, density and housing considerations. Also, given the rise of African cities, where some are being completely designed and developed in lieu of developing organically, the results of this project will make recommendations for effective metropolitan growth structures. (Received September 14, 2013)

1096-00-1344 **Wenrui Hao*** (hao.50@mbi.osu.edu), Jennings Hall 3rd Floor, 1735 Neil Ave., columbus, OH 43210. *Applications of homotopy method to differential equation.*

This talk will cover some recent progress on numerical methods to solve systems of nonlinear partial differential equations (PDEs) arising from biology and physics. This new approach, which is used to compute multiple solutions and bifurcation of nonlinear PDEs, makes use of polynomial systems (with thousands of variables) arising by discretization. Examples from biological models will be used to demonstrate the ideas. (Received September 15, 2013)

1096-00-1350 **John A. Velling*** (jon.scott@montgomerycollege.edu), **Terrence Blackman** and **Jerald Smith**. *Collaborative Research: Maplets for Calculus – Incorporating the M4C into MathLynx.*

None (Received September 15, 2013)

1096-00-1498 **Joyati Debnath*** (jdebnath@winona.edu), Department of Mathematics and Statistics, Winona State University, Winona, MN 55987. *Women in Research, Professional Growth and Services.*

The presentation will focus on role of women in academics and professional services with particular emphasis on personal and professional growth as well as scholarly activities and research. The presentation will explore personal ideas, experiences and guidance for possible success in the academic fields. Some potential research directions in STEM fields will also be addressed. (Received September 16, 2013)

1096-00-1505 **Eric M Friedlander***, Department of Mathematics, University of Southern California, Los Angeles, CA 90089. *Reflections on a Mathematical World.*

The title of Bob Dylan's 1964 album "The times they are a-changin'" has been less applicable to our mathematical world than to many others. But partly because of what we mathematicians have accomplished and even more because what society expects of us, this seems to be appropriate for Mathematics in the next two decades. This talk will reflect upon the evolution of the mathematical community during the past 50 years, and encourage more active participation by many in shaping the role to be played by mathematicians in the near future. (Received September 16, 2013)

1096-00-1510 **Alexander Its*** (itsa@math.iupui.edu), Department of Mathematics, Indiana university-Purdue University, 402 N. Blackford, LD 270, Indianapolis, IN 46202. *On the higher universality classes in the random matrix model.*

We will discuss the asymptotic analysis of the Painlevé - type Fredholm determinants describing (a) the edge eigenvalue behavior in unitary random matrix models with critical edge points, and (b) the critical behavior of the eigenvalue gap probabilities in the same model near a quadratic zero of the limiting mean eigenvalue density. In the first case, the determinant is associated with the Painlevé I hierarchy, and it represents the higher order analog of the beta=2 Tracy-Widom distribution. In the second case, the kernel is given in terms of the second Painlevé equation, and it represents the higher order analog of the classical sine-kernel determinant. In the both cases, we will present the large gap asymptotic expansion, including the constant terms. The talk is based on the joint works with T. Bothner, T. Claeys, and I. Krasovsky. (Received September 16, 2013)

1096-00-1604 **Saliha Pehlivan*** (salihapehlivan@gmail.com), FL. *Linearly Connected Sequences and Spectrally Optimal Dual Frames for Erasures.*

In the case that a frame is prescribed for applications and erasures occur in the process of data transmissions, the question of characterizing optimal dual frames naturally arises. If iterations are allowed in the reconstruction process of the signal vector, then spectral radius measurement for the error operators is more appropriate then the operator norm measurement. We obtain a complete characterization of spectrally oneerasure optimal dual frames in terms of the redundancy distribution of the prescribed frame. Our characterization relies on the connection between erasure optimal frames and the linear connectivity property of the frame. We prove that the linear connectivity property is equivalent to the intersection dependence property, and is also closely related to the well-known concept of k-independent set. Additionally we also establish several necessary and sufficient conditions for the existence of an alternate dual frame to make the iterated reconstruction to work. (Received September 16, 2013)

1096-00-1734 **Jenny McNulty*** (mcnulty@mso.umt.edu). *Math Beyond the Classroom.*
Student who like doing puzzles, looking for patterns and solving problems are invited to attend Missoula Math Day, a one day event held at the University of Montana, and Missoula Math Circle, an afterschool enrichment program. The goals of these activities are to change students' perception of what math is, to rekindle an appreciation, love and passion of the subject. This talk will include a discussion of our successes and struggles of providing enrichment activities to students in grades 8 -12 in rural Montana. This project, run jointly with Kelly McKinnie and Ke Wu, has been funded by the MAA DMEG program. (Received September 16, 2013)

1096-00-1811 **Fernando Quintino*** (fernandoquintino@live.com), 2446 Nutwood Ave. Apt H37, Fullerton, CA 92831. *Interpolating Legendre multiplier sequences.*
In an attempt to find a class of functions interpolating Legendre multiplier sequences (LMS) we examine the order of an entire function whose zeros belong to a sector which contains the zero loci of quadratic polynomials interpolating LMS. The talk will describe our methods, some results, and will conclude with open questions. (Received September 16, 2013)

1096-00-1911 **Michael Filippakis*** (mfilip@unipi.gr), Department of Digital Systems, University of Piraeus, 18534 Piraeus, Greece. *Nodal Solutions for Neumann Problems with a Nonhomogeneous Differential Operator.*
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 16, 2013)

1096-00-2033 **Usha Kotelawala*** (jon.scott@montgomerycollege.edu) and **Robert Graham**. *Collaboration, Observation, and Revision: Lesson Study in Teacher Preparation.*
None (Received September 17, 2013)

1096-00-2327 **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. *Logarithmic Potential on a Triangle.* Preliminary report.
This talk will examine the extremal placement of small numbers of logarithmic charges located on an equilateral triangle-shaped domain. The placement of these charges will be discussed, and future work regarding different geometric domains and numbers of charges will be discussed. (Received September 17, 2013)

1096-00-2663 **James Garnett Sawyer*** (6dimensiondesign@gmail.com), 241 1/2 Lexington, Buffalo, NY 14222. *Graph Theory Conjectures Triangular Planes from Nash/Williams (hexagonal graphs) with Buckminster Fuller's Triangular Tetrahedral Planes forming a Six Dimensional Triangular Coordinate.* Preliminary report.
Today we use the Cartesian coordinate system. The Coxeter polytype polyhedrons describe polyhedrons using 6 dimensions using Cartesian coordinates of (x,y,z) cubic based algebra. We describe the triangular planes of the tetrahedron, octahedron and icosahedron.This Paper compares and presents papers related to triangular planes of triangular polyhedrons and the square planes of polyhedrons including the cube using a simplified Euler foundation based on the algebra of(r,s,t,u,v,w). The Pythagorean theorem is squared and triangulated as a study to develop and compare square graphic space to triangular graphic space. Fermat's and Beal's Conjecture as number theory are connected to graph theory in this document. Cartesian Philosophy of (x, y,z) axes of symmetry related to (r,s,t,u,v,w) represented as graphic planes. Thus a form of dual coordinate system is formed which connects the square planes of the 3-Dimensional Coordinate system and (x,y,z) with the triangular planes of the 6-dimensional Coordinate system (r,s,t,u,v,w) edges of Six Dimensional Tetrahedral Theory references(based on

6 edges of tetrahedron). The volume of space theory is connected between Beal Conjecture number theory and 6 dimensional volume of the tetrahedron in Six Dimensional Space Theory. (Received September 17, 2013)

1096-00-2695 **Rebecca Plassmann*** (rplassmann@cocc.edu), Central Oregon Community College, 2600 NW College Way, Bend, OR 97701. *Using Knitting To Construct Seamless Regular and Semi-Regular Polyhedra.*

In this presentation, I will describe the seamless construction of the five regular (and some of the semi-regular) polyhedra using knitting. Each of these models illustrates the three dimensional object falling through a plane and therefore revealing its structure in a series of polygonal cross sections. Each of the polyhedra has a different symmetry, and therefore a different preferred method of construction. For instance, the icosahedron is most symmetrical, and therefore easiest to knit, if constructed from vertex to vertex, while its dual, the dodecahedron, is most easily constructed from the center of one face to the center of the opposite face. (Received September 18, 2013)

1096-00-2755 **Patrick Callahan*** (callahan.web@gmail.com), 823 H Avenue, Coronado, CA 92118-2521. *Pre-Service Teacher Task Study Project.*

The Pre-Service Teacher Task Study Project (PST-TSP) is a cross-site model where instructors of pre-service content and methods courses from different universities use Illustrative Mathematics as a way for their students to learn about the CCSSM. The project is flexible with respect to content and is designed to fit easily within existing courses. The purpose of the project is for pre-service teachers to gain experience with the Common Core by working through illustrative tasks, critiquing tasks written by others, and writing tasks and responding to feedback given by others.

The pre-service teachers are introduced to the Illustrative Mathematics professional community of educators to participate in and provide support as they become teachers.

We have piloted this program twice with about 100 students from 6 universities participating. This talk will share some details about the project and discuss ideas for the future. (Received September 18, 2013)

1096-00-2762 **Eoin J Elliffe*** (eoin.elliffe@lfg.com). *Risk management of volatility controlled variable annuity contracts.*

Traditionally there has been little activity in the reinsurance market for the multiple trillion dollar variable annuity, VA, industry. The academic literature explains that the risks in VA contracts have been under-priced and therefore leave little room for prudent risk management practices. With the introduction volatility controlled funds we show that this is no longer the case. Specifically we show that a dramactic reduction in hedge cost can be achieved with the appropriate volatility control mechanisms applied to both asset allocation and pure equity funds. (Received September 18, 2013)

01 ► History and biography

1096-01-19 **Steven H. Weintraub*** (shw2@lehigh.edu), Dept. of Mathematics, Lehigh University, Bethlehem, PA 18015. *The irreducibility of the cyclotomic polynomials.*

It is a basic theorem of number theory that the cyclotomic polynomials are irreducible. This was first proved in the prime case by Gauss and in the general case by Kronecker, and has been reproved many times by many mathematicians. In this talk we will examine various proofs, not only for their intrinsic interest but also for the light they shed on the background knowledge and concerns of the mathematicians of the time. (Received May 15, 2013)

1096-01-95 **Joseph P Kung*** (kung@unt.edu), Department of Mathematics, 1155 Union Circle #311430, Denton, TX 76203. *Transvectants and finiteness: Gordan's way of doing invariant theory:.* Preliminary report.

I will attempt to reconstruct Gordan's thinking on questions in invariant theory, particularly his way of proving the theorem that the covariants of binary forms can be generated from a finite set of covariants. Any such reconstruction can only be conjectural, and so I will be presenting "historical fiction", not "history." I will show that Gordan's thinking is more attuned to the twenty-first century than Hilbert's, and that Hilbert owed more to Gordan than he was willing to admit. With Gordan's posthumous reputation as an example, we will also discuss the issue of how reputations are (cyclically?) created and destroyed in mathematics. (Received July 25, 2013)

1096-01-100 **Janet E Barber*** (barbe2je@cmich.edu), 301 Largo Road, Largo, MD 20774, and **Asamoah Nkwanta**. *Benjamin Banneker's Original Handwritten Document: Observations and Study of the Cicada.*

"Benjamin Banneker and his Romance with the Cicada: A Social Science-STEAM Connection" is a presentation extracted from the above titled paper. The "A" will be added to STEM here as an artistic and social science delivery in explanation of Benjamin Banneker's fascination with and his research and study of the cicada. Banneker was an African-American mathematician, astronomer, farmer, and scientist. A previously unpublished handwritten document by Banneker, mathematical models involving the periodic cycle and behavior of the cicada, and stories of the scientist behind the science will be discussed and shared in this talk. Banneker is known for his mathematical puzzles, ephemeris calculations, almanacs, creation of a wooden clock, land surveying, and a famous letter on human rights written to the 3rd U.S. President, Thomas Jefferson. Though Benjamin Banneker is among the first American scientists to document and record chronological information of the seventeen-year cycle of the periodic Magicicada – Brood X, also known as the Tibicina Septendecim cicada, his observations of the cicadas are much less known, taught, and publicized. (Received July 28, 2013)

1096-01-104 **Scott W. Williams*** (bonvibre@yahoo.com), 44 Highgate Ave., Buffalo, NY 14214-1409. *African Americans in Topology.* Preliminary report.

We sketch biographies of a few from a list of 20 African Americans whose degree and/or research interests focused upon Topology: Joseph Battle, Simmie S Blakney, George H Butcher, Jesse P Clay, William W. S. Claytor, Melvin R Currie, Dennis Davenport, James Joseph, Louis C Marshall, John H McAlpin, James Nelson jr, Nathan F. Simms jr, Robert S. Smith, Beauregard Stubblefield, Evelyn Thornton, Donald Weddington, James E White, Scott W Williams, and Dudley Weldon Woodard. (Received July 29, 2013)

1096-01-131 **Donald R. King*** (d.king@neu.edu), 567 Lake Hall, Northeastern University, Boston, MA 02115. *Mathematicians of the African Diaspora on the Web.* Preliminary report.

African Americans are significantly under represented among US citizens receiving PhDs in the mathematical sciences and among the faculties of US departments and graduate programs granting PhDs in the mathematical sciences. These facts are closely related and are well documented. The web site http://www.math.buffalo.edu/mad/ created by Professor Scott Williams in 1997 has been an influential and heavily used resource on the contributions of Africa and the African Diaspora to mathematics. A group of mathematicians is working to convert Scott Williams' site into a searchable database. We will introduce this new site www.mathad.com and discuss ways in which the web can be used effectively to help produce African American math PhDs and enhance their research careers. (Received August 02, 2013)

1096-01-196 **Paul R Bouthellier*** (pbouthe@pitt.edu), 504 East Main Street, Titusville, PA 16354. *The Quaternion Wars: The 1890s and the Present.*

In this talk we shall consider the history of quaternions from their creation by Hamilton in 1843 to their use in modern computer graphics. In particular we shall consider the mathematical atmosphere that existed at the time of their creation, the vector vs quaternions wars of the 1890s, and the current debate over the use of quaternions in computer graphics today. Of particular interest is how the debate in the computer science community today over the best way to create rotations closely mirrors the debate in the physics and mathematics community of over one hundred years ago-with the current participants invoking the arguments of Gibbs, Heaviside, and Tait to justify their own views. Matrix and quaternions based rotations and interpolations will be illustrated and compared using graphics packages such as Studio 3D Max, Poser, and Flash. (Received August 15, 2013)

1096-01-222 **June E. Barrow-Green*** (june.barrow-green@open.ac.uk), Faculty of Mathematics, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom. *"Merely a speculation of the mind?" William Henry Fox Talbot and mathematics.*

A product of the Cambridge Mathematical Tripos of 1820, William Henry Fox Talbot sustained an active interest in mathematics throughout his life. He published several mathematical papers – both his first and his last scientific publications were in mathematics – and in 1838 he was awarded the Royal Society's Gold Medal for papers in which he proved theorems about elliptic integrals. But for Talbot mathematics was never a career – he is famous today as a pioneer of photography – and his mathematical achievements, lauded at the time, were soon largely forgotten. But to consider Talbot's mathematics solely in terms of his contributions to the mathematical canon would be to do it an injustice. As his Mathematical Notebooks show, mathematics for Talbot was not just about proving theorems: it was a subject he enjoyed in its own right and it was a subject which provided him with a model for scientific investigation. (Received August 21, 2013)

1096-01-233 **James T Smith*** (smith@sfsu.edu). *Tarski in Poland: Teaching and Teacher Training.*
The presenter and coeditors Andrew and Joanna McFarland have completed a book, Alfred Tarski, "Early Work in Poland: Geometry and Teaching, with a Bibliographic Supplement," for publication by Birkhäuser. It contains translations and background for some of Tarski's early work on geometry, which will now be entirely accessible in English, and all of Tarski's other work that remained only in Polish; and it updates Steven Givant's 1986 Tarski bibliography. It supplements the wonderful 2004 biography of Tarski by Anita and Solomon Feferman. During 1925–1939 Tarski was a full-time Warsaw high-school teacher and part-time University researcher and lecturer, particularly in courses for teachers. Many of the translations in the new book relate to Tarski's work in mathematics education. This talk describes the new book and stresses that aspect of his career, which is hardly known today, in spite of Tarski's fame as a logician. (Received August 21, 2013)

1096-01-321 **Judith R. Goodsein*** (jrg@caltech.edu), Einstein Papers Project, MS 1-20, Pasadena, CA 91125. *Tullio Levi-Civita, Giuseppe Levi and the Fascist Loyalty Oath of 1931.* Preliminary report.
While American mathematicians and physicists are familiar with the Levi-Civita symbol in tensor calculus, few are likely to know his personal history (let alone the correct pronunciation of his name). This talk considers the historical framework for the events leading up to the 1931 oath of allegiance to the Fascist government, which all of Italy's university professors were required to sign, and how the Roman mathematician Tullio Levi-Civita and Turin's professor of anatomy Giuseppe Levi responded. (Received August 28, 2013)

1096-01-332 **Erica N Walker*** (ewalker@tc.edu). *"Representing the Race": Black Mathematicians and the Paths to Excellence.*
In this talk, I describe selected findings from a research study exploring the formative, educational, and professional experiences of Black mathematicians in the United States. These findings draw upon interviews and archival research with and related to Black mathematicians. This presentation will focus on themes from a forthcoming SUNY Press book on Black mathematicians to be published in 2014, and will include an analysis of the multi-generational mathematics communities and networks supporting Black mathematics talent; the role of Black institutions (schools, colleges, and organizations) in developing mathematicians; and the ways in which race and racialized experiences have been experienced by mathematicians past and present. (Received August 28, 2013)

1096-01-395 **Daniel S Silver*** (silver@southalabama.edu), Department of Mathematics and Statistics, ILB 325, Mobile, AL 36688. *Knots in the Nursery: "(Cats) Cradle Song" of James Clerk Maxwell.*

PETER the Repeater
Platted round a platter
Slips of slivered paper,
Basting them with batter.

So begins "(Cats) Cradle Song," verse composed by James Clerk Maxwell, probably in 1877. It was Maxwell's response to the manuscript of "On Knots," written by his friend Peter Guthrie Tait, who had hoped for constructive criticism.

Maxwell wrote poems to amuse his friends and express personal sentiments. The purpose of "(Cats) Cradle Song" was to have a bit of good-natured fun at Tait's expense. Between its lines, however, we find references to mathematical ideas that were novel at the time. Some of the ideas would endure and inspire succeeding generations. (Received September 01, 2013)

1096-01-401 **James J. Tattersall*** (tat@providence.edu), Department of Mathematics, Providence College, Providence, RI 02918, and **Shawnee L. McMurran** (smcmurra@csusb), Department of Mathematics, California State University, San Bernardino, CA 94207. *Dear Professor Richardson.* Preliminary report.
Caroline Eustis Seely (1887-1961) received her Ph.D. from Columbia University in 1915 under the supervision of Edward Kasner. She was the first mathematician to be employed full-time by the American Mathematical Society. Seely served as a clerk for Frank Nelson Cole and R.G.D. Richardson when they were Secretaries of the AMS. She also worked as an editorial assistant for the *Bulletin* and the *Transactions*. We focus on her work for the AMS and the correspondence between her and Richardson during the period from 1921 to 1934. (Received September 02, 2013)

1096-01-421 **Peggy Aldrich Kidwell***, MRC671, NMAH, Smithsonian Institution, P.O. Box 37012, Washington, DC 20013-7012. *Playing Checkers with Machines – from Ajeeb to Chinook.* Preliminary report.

Checkers-playing automata – their moves directed by hidden human operators – have been known since the eighteenth century. Chess-playing androids that also played checkers were soon built in Italy, Bavaria, and then England. The third of these, Ajeeb, came to the United States, spending much of the time from 1885 into the 1930s based in New York and taking occasional tours around the country. The advent of electronic computers in the mid-1940s led to new attempts to play games using machines, both in Britain and the United States. By the end of the twentieth century, a Canadian-written computer program, Chinook, had defeated world champion and mathematician Marion Tinsley. More recently, the developers of Chinook announced that checkers, like Nim and tic-tac-toe before it, could always be played to a draw. (Received September 03, 2013)

1096-01-424 **Amy Ackerberg-Hastings*** (aackerbe@verizon.net). *The History of Slide Rules, As Told by the Smithsonian Collections.*

Although it has been more than forty years since slide rules passed out of daily practice for most mathematicians and engineers, the instruments are nostalgically remembered as part of our common heritage. Historians study slide rules to better understand the evolution of computation, instrumentation, and even connections between these objects and the wider culture. Some mathematics teachers offer instruction in slide rules to help students visualize the process of calculation. The Smithsonian Institution recently digitized over 250 slide rules and related documentation from the mathematics collections, organizing these records into an online exhibit at http://americanhistory.si.edu/collections/object-groups. Some instruments in other collections are also available for public view via http://collections.si.edu. While this talk does not promise the epic narrative of a Hollywood blockbuster, it will briefly trace, the 400-year history of slide rules by focusing on those aspects of the story that are especially well-documented by this collection. We will also note how organizing the collection in different ways reveals different aspects of how these instruments changed over time. (Received September 03, 2013)

1096-01-463 **Eisso J. Atzema*** (atzema@math.umaine.edu). *Classifying Quadrilaterals.* Preliminary report.

In the definitions of Book 1 of Euclid's Elements one can find a rudimentary classification of the quadrilaterals. By and large, the same classification is still taught today. Over time, however, various changes from Euclid became commonplace and at least one new type of quadrilateral was introduced. In this talk I will look at the history of the classification of quadrilaterals from the mid-16th century through the 19th century. Particularly, I will focus on how the development of mathematics might have impacted the teaching of the classification of quadrilaterals. I will also have a look at the history of the notion of the general or "irregular" quadrilateral. (Received September 04, 2013)

1096-01-466 **Walter J. Meyer*** (meyer1@adelphi.edu). *The Cajori Two Project.* Preliminary report.

For some years now, the Cajori Two Group has been assembling a digital database of American college mathematics curricula throughout the 20th century. This database, extracted from college catalogs, covers 20 campuses at 10 year intervals from 1905 to 2005. Software has been written for analysis and display, including a website for on-line interaction. This talk will outline what we did in more detail and present some initial results about the growing curricular diversity of the 20th century. (Received September 04, 2013)

1096-01-514 **James A. Donaldson*** (jdonaldson@howard.edu), Department of Mathematics, College of Arts and Sciences, Howard University, Washington, DC 20059. *Mathematics at Howard University: 1900 – 1960.* Preliminary report.

Around the turn of the twentieth century, the discipline of mathematics was in a very early stage of development in the United States of America. The founding of the New York Mathematical Society in 1888 marked the beginning of the ascendance of mathematics in this country. In this paper, we describe some Howard University contributors to mathematics and their contributions during the first six decades of the twentieth century. (Received September 05, 2013)

1096-01-518 **Gregg De Young*** (gdeyoung@aucegypt.edu). *Rediscovering George Strachan's Euclid.*

George Strachan, a Scottish orientalist who traveled extensively in the Eastern Mediterranean at the beginning of the seventeenth century, left only one noteworthy legacy — his personal collection of Arabic and Persian manuscripts. In 1621, Strachan sent 61 manuscripts from Isfahan to Aleppo, the first stage of their journey back to Europe. Today, 25 of his manuscripts can be located in the Vatican Library and a further 12 have been identified in the Biblioteca nazionale Vittorio Emanuele III (Naples). Among these 37 manuscripts, only Naples III.F.31 (containing a Persian treatise on spherical astronomy by Naṣīr al-Dīn al-Ṭūsī as well as two short Persian tracts on arithmetic) dealt with mathematical topics. A second mathematical manuscript — an Arabic version of the *Elements* — owned by Strachan has now been identified in the Majlis Shūrā Library (Tehran). We describe the essential characteristics of this serendipitously discovered manuscript and assess its significance for the history of the *Elements* in Arabic. (Received September 05, 2013)

1096-01-536 **Earl R Barnes*** (earl.barnes@morgan.edu), Earl R. Barnes, 3880 Greensboro hwy, Madison, GA 30650. *Learning Mathematics With Clarence Stephens.*

In 2003 the Mathematical Association of America gave Clarence Stephens its Gung and Hu award for outstanding service to mathematics. It was noted that in 1987 the mathematics program at SUNY Potsdam, where Stephens was Chair, graduated 184 mathematics majors, the third largest number of any university in the U.S. for that year. This achievement was all the more remarkable when one considers that SUNY Potsdam had a total enrollment of fewer than 5000 students. The techniques Stephens used to attract students to mathematics at Potsdam were begun at Morgan State College years earlier. In this talk we give some personal reminiscences about Stephens and his teaching techniques, and especially the Morgan years. (Received September 05, 2013)

1096-01-563 **David Lindsay Roberts*** (robertsdl@aol.com). *The Influence of Some Twentieth-Century American Popularizers of Mathematics: E. T. Bell, Edward Kasner, James Newman, and Lillian Lieber.* Preliminary report.

Between 1937 and 1942 there appeared three books aimed at bringing certain aspects of mathematics to a wider public: *Men of Mathematics* by E. T. Bell; *Mathematics and the Imagination* by Edward Kasner and James Newman; and *The Education of T. C. MITS* by Lillian Lieber. All three achieved substantial initial success, and they have continued to attract readers to the present day. But they are very different books, with differing aims, and their authors had disparate backgrounds and careers. An examination of the reception of these books by the academic mathematics community and by the wider public illuminates the potential and the limitations of mathematics popularization. (Received September 06, 2013)

1096-01-591 **anthony j. crilly*** (t.crilly@btinternet.com), Dr Anthony J. Crilly, St Albans, Herts. AL1 3PB, United Kingdom. *The launch of invariant theory: seeking and finding.*

Invariant theory made a promising start in the 1840s, first guided by Arthur Cayley acting on a suggestion by George Boole, which then attracted James Joseph Sylvester. It acted as a unifying agent through its connections with the algebraic and geometric problems of the day. What were the immediate objectives of the early pioneers and how were they accomplished? Placing ourselves in the 1840s and 1850s, the period prior to the luxuriant growth of the subject in the second half of the nineteenth century, we survey the aims and methods adopted. (Received September 07, 2013)

1096-01-597 **Yibao Xu*** (yxu@bmcc.cuny.edu), 199 Chambers Street, New York, NY 10007. *Sino-US Mathematical Relations: 1950s–1970s.* Preliminary report.

When the Communist Party assumed power in mainland China in 1949, diplomatic relations between the US and China came to an end. Chinese mathematicians who had studied or taught in American institutions suddenly had difficult decisions to make: either to remain in the US as did Shiing-Shen Chern, or return to China as did Hua Luogeng. In the meantime, planned visits of American mathematicians and other activities in mainland China were terminated. However, in the 1950s and 1960s, Sino-US mathematical relations were kept alive through Taiwan, where the Nationalists under Chiang Kai-shek took refuge. Chinese students from Taiwan came to study in America and the Chinese-American mathematicians went to Taiwan helped in the development of mathematics there. Subsequently, President Nixon's famous visit to China in 1972 had a dramatic impact on relations among the US, mainland China, and Taiwan. Visits and exchanges of mathematicians started soon thereafter and gradually increased throughout the 1970s. Based on various primary sources, this paper presents a preliminary account of Sino-US mathematical relations from the 1950s to the 1970s. (Received September 07, 2013)

1096-01-660 **Maritza M. Branker*** (mbranker@niagara.edu), Department of Mathematics, Niagara University, NY. *Analogy in William Rowan Hamilton's treatment of complex numbers.*

This talk will deal with the use of analogy in William Rowan Hamilton's 1837 treatise. It is based on the joint work of J. Little and Maritza M. Branker, encapsulated in their 2012 article entitled Analogy in William Rowan Hamilton's New Algebra. We will discuss Hamilton's extension of the mathematical landscape to include complex numbers. In the 19th century mathematicians were largely uneasy with the idea of complex numbers and Hamilton's justification of their use is notable but largely overlooked in favour of his impressive work on quaternions. (Received September 08, 2013)

1096-01-741 **Ronald E. Mickens*** (rmickens@cau.edu), Clark Atlanta University, Box 1744-, Physics Department, Atlanta, GA 30314. *Albert Turner Bharucha-Reid.*

Albert Turner Bharucha-Reid (13 November 1927-26 February 1985) had a distinguished career in both pure and applied mathematics. His many contributions to research, student training and mentoring, and academic and professional leadership were acknowledged by various honors and awards he received throughout his life. His first book, Elements of the Theory of Markov Processes and Their Applications, provided one of the first concise introductions to the area of probabilistic analysis and for many years was successful as a textbook and guide for self-study. He published more than seventy papers and authored seven books on topics in the stochastic theory of epidemics, Markov process, random integral and polynomial equations, and computational methods. His last book, with M. Sambandham, Random Polynomials, was published posthumously in 1986. The major purpose of this presentation is to provide some insights into Professor Bharucha-Reid's life and family, professional career, and research areas. To aid in this task a large number of photos will be shown. Of both great interest and significance is the fact that he never received the formal doctoral degree in mathematics. (Received September 09, 2013)

1096-01-745 **Maria R. Zack*** (mzack@pointloma.edu), Mathematical, Information & Computer Sciences, Point Loma Nazarene University, 3900 Lomaland Drive, San Diego, CA 92106. *John Wallis' Computations on the Cycloid.*

In De Cycloide (1659) John Wallis described his own computations on the cycloid as well as those of several other scientists including Christopher Wren. This talk will consider the Wallis-Wren computation of the length of the cycloid. (Received September 09, 2013)

1096-01-791 **Craig G Fraser*** (craig.fraser@utoronto.ca), Inst. Hist. & Phil. of Sci. & Tech., Victoria College, University of Toronto, Toronto, Ontario M5S 1K7, Canada. *Infinitesimals in Analysis 1780-1830.* Preliminary report.

In 1982 Joe Dauben explored the implications of Abraham Robinson's invention of non-standard analysis for the history and philosophy of mathematics. Dauben drew attention to a body of historical work – concentrated mainly on Augustin-Louis Cauchy – that centered on a reevaluation of the concept of infinitesimal in light of Robinson's (and other's) discoveries.

While not particularly focused on Robinson's work itself, my paper will contribute to the discussion through an examination of infinitesimals and the logic of the calculus around 1800. The emphasis will be on mathematical issues. I evaluate the role infinitesimals played in new mathematical work of the period, and the extent to which they posed foundational issues for researchers. Particular attention will be devoted to the place of infinitesimals in Cauchy's writings on analysis.

Reference

Joseph W Dauben, "Abraham Robinson and Nonstandard Analysis: History, Philosophy, and Foundations of Mathematics." *History & Philosophy of Modern Mathematics. Volume 11: Minnesota Studies in Philosophy of Science*. 1988. Eds. William Aspray and Philip Kitcher. Pp. 177-200. University of Minnesota Press.
(Received September 10, 2013)

1096-01-794 **Michel Pierre Serfati*** (michel.serfati@univ-paris-diderot.fr). *On the representation of 'abstract' algebras by 'concrete' ones, and the rise of spectral methods : Marshall Stone's representation theorems (1936-1938).*

The work of Marshall Stone in the years 1936-1938 marked a major epistemological jump. Starting with an apparently very thin question, namely to obtain a 'concrete' representation of 'abstract' Boolean algebras, Stone, in two years and five articles, brought to light, little by little, an outstanding method between algebra and topology, now called spectral analysis. The presentation will identify the main epistemological stages of this creation. (Received September 10, 2013)

1096-01-797 **Michel Pierre Serfati*** (michel.serfati@univ-paris-diderot.fr). *The transcendence of e in the 1870s. The story of a theorem.*

The first proof of the existence of transcendental numbers was produced by Liouville in 1844. However, it is an ad hoc construction, which gave no information on the usual numbers of Analysis. In 1873, in four Compte Rendus à l'Académie des Sciences, Charles Hermite established a remarkable proof of the transcendence of e. In this paper, we analyze the mathematical details, as well as the origin of this theorem. One has not found today still, according to M. Waldschmidt, a method of proof of transcendence which is fundamentally different from Hermite's (Received September 10, 2013)

1096-01-919 **Victor J Katz*** (vkatz@udc.edu), 841 Bromley St., Silver Spring, MD 20902. *Group Theory and the Bumpy Road to Abstraction.* Preliminary report.

Although the idea of a group was present in the work of Galois in 1830 and was explicitly defined by Arthur Cayley in 1854, it took until late in the nineteenth century before the idea of a group became part of the mathematical mainstream. And even then, groups, especially groups of permutations, were generally thought of simply as useful tools for determining whether polynomial equations could be solved by radicals. In fact, through the end of the century, the central goal of algebra was still, as it had been for centuries, the solving of equations. We will explore in this talk some of the reasons for the long gestation period between the conception of the idea of a group and the birth of the notion that such an abstract concept should serve as the basis for the study of algebra. (Received September 17, 2013)

1096-01-965 **William Thomas Archibald*** (tarchi@sfu.ca), Dept of Mathematics, Simon Fraser University, Burnaby, BC V5A1S6, Canada. *Visual Representation in the Theory of Algebraic Functions and their Integrals in the late 19th Century.*

Riemann's definition of the "Riemann surface" and his use of this tool in his theory of Abelian functions provoked a great deal of interest in understanding how to use these objects effectively, especially after the geometric interpretation by Clebsch. It has often been observed – Weyl alludes to it in his 1913 monograph - that the vagueness of the definition was an obstacle to its successful use. However, the late nineteenth century saw a variety of techniques for attempting to understand what a Riemann surface was, and there are interesting attempts at creating understanding and insight via the use of graphical methods. Building on work by Bruno Belhoste, in this paper we shall look at several such representations, focussing on the methods of Paul Appell and Édouard Goursat for the study of algebraic functions. (Received September 11, 2013)

1096-01-973 **James T Smith*** (smith@sfsu.edu), 1363 27th Avenue, San Francisco, CA 94122. *Tarski in Poland: new translations and background.*

The presenter and coeditors Andrew and Joanna McFarland have completed a book, Alfred Tarski, "Early work in Poland: geometry and teaching, with a bibliographic supplement," for publication by Birkhäuser. It contains translations and background for some of Tarski's early work on geometry, which will now be entirely accessible in English, and all of Tarski's other work that remained only in Polish; and it updates Steven Givant's 1986 Tarski bibliography. It supplements the wonderful 2004 biography of Tarski by Anita and Solomon Feferman. Ten of the new translations fall in the area of logic: Tarski's 1921 paper on well-ordering, his first paper on the concept of truth (presented in Lwów in December 1930), and eight brief discussions at various conferences from 1925 to 1936. This talk describes the new book, emphasizing a selection of those items, and gives a glimpse of Tarski's approach to logic in materials for high-school students. (Received September 11, 2013)

1096-01-1003 **Harold M. Edwards*** (edwards@cims.nyu.edu), Courant Institute, 251 Mercer St., New York, NY 10012. *Abel's Version of Abel's Theorem.*

Abel first stated what has become known as "Abel's Theorem" in 1826, when the theory of functions of a complex variable was in its infancy and the theory of Riemann surfaces had not been invented. The talk will explain in elementary terms how Abel formulated the theorem without these theories that are central to the modern formulations. It generalizes to a wide class of transcendental functions—now called Abelian integrals—what Abel saw as the essential property of elliptic integrals, namely, the addition law on elliptic curves. (Received September 12, 2013)

1096-01-1007 **Fernando Q. Gouvêa*** (fqgouvea@colby.edu), Dept. of Mathematics and Statistics, Colby College, 5836 Mayflower Hill, Waterville, ME 04901. *The Linear Algebra of Tevfik Hussein Pasha.* Preliminary report.

Long before there was a subject called "linear algebra," a high official of the Ottoman empire published a book, in English, called *Linear Algebra*. We will give a quick account of the book and its contents, and comment on some historical questions it raises. (Received September 12, 2013)

1096-01-1036 **Mohammad Moazzam*** (mxmoazzam@salisbury.edu), Department of Mathematics and Comp. Sci., Salisbury University, 1101 Camden Ave, Salisbury, MD 21801. *Nairizi: A Persian Mathematician For Consideration.*

The list of mathematicians that are named in the ever increasing history of mathematics saga needs the addition of a name: Persian mathematician Nairizi. The purpose of this presentation is to highlight some of Nairizi contributions to mathematics and other sciences. Then each person who attends can better assess whether or not Nairizi is a candidate for inclusion on the list. (Received September 12, 2013)

1096-01-1103 **Joel S. Silverberg*** (joel.silverberg@alumni.brown.edu), 31 Sheldon St, Providence, RI 02906. *The Plain and Gunter's Scales – Seventeenth Century Additions to the Toolbox of Students and Practitioners of the Mathematicks.*

From the early through the mid- seventeenth century a series of mathematical instruments termed plain scales, gunter's scales, and sectors were developed in order to inform mathematical practitioners in dialing, astronomy, and navigation of the theoretical foundations of their sciences and to reduce the burden of the plane and spherical trigonometric calculations inherent in their practice. These scales appeared as figures in published books, and were embedded in cross-staffs, rules, gauging rods, and sectors, constructed from a variety of materials including wood, brass, and ivory.

Due to limitations of time I shall restrict my discussion to the first two of these types of scales – plain scales and gunter's scales. I will first outline their mathematical use in teaching definitions and behaviors of trigonometric functions to mathematical practitioners in a manner which facilitated their direct application to problem solving through the use of proportionality and ratio (as opposed to algebraic manipulation), and shall demonstrate the effectiveness of these tools and methods in solving problems in navigation and in surveying. (Received September 12, 2013)

1096-01-1125 **Sloan Evans Despeaux*** (despeaux@wcu.edu), Department of Mathematics and CS, 425 Stillwell, Western Carolina University, Cullowhee, NC 28723. *Mechanics and Mathematical Physics in Nineteenth-Century Britain: An Overview.*

More than any other fields of mathematics, mathematical physics and mechanics attracted the most renowned nineteenth-century British mathematicians. William Thomson (later Lord Kelvin), George Gabriel Stokes, William Rowan Hamilton, James Clerk Maxwell, and George Green, among others, are today memorialized through theorems, equations and laws. Besides profiting from the creative output of these mathematical stars, mathematical physics and mechanics occupied a considerable amount of space in British scientific journals. This talk will explore what forces directed this wealth of talent into these fields and encouraged such activity in British scientific journals. (Received September 13, 2013)

1096-01-1274 **Joseph W Dauben*** (jdauben@att.net), Herbert H. Lehman College, The City University of New York, 250 Bedford Park Blvd. West, Bronx, NY 10468. *Circles and Spheres: A Comparison of Chinese and Greek Arguments and Proofs.*

The year 2013 marked the 1750th anniversary of Liu Hui's annotated edition of the ancient Chinese classic text, *The Nine Chapters on the Art of Mathematics*. Even earlier mathematical works survive on bamboo strips dating to mathematics of pre-Qin times. An examination of these early works, including Liu Hui's approach to problems involving circles and his partial success in deriving the volume of the sphere as well as the later completion of Liu Hui's unfinished analysis of the problem by Zu Gengzhi, invites comparison with the achievements of ancient Greek mathematics and the results of Euclid and Archimedes in particular. Since the Archimedes codex relevant to these matters is now at the Walters Art Museum undergoing conservation and analysis, it seems appropriate to consider in particular the similarities and differences between the approaches Chinese and Greek mathematicians took to attack the problems of circles and spheres in all of their mathematical complexity. (Received September 14, 2013)

1096-01-1299 **Robert E. Bradley*** (bradley@adelphi.edu), Adelphi University, Dept. of Mathematics & Computer Science, 1 South. Ave., Garden City, NY 11530. *The Geometric Calculus of Bernoulli and l'Hôpital.*

The Marquis de l'Hôpital published the first calculus textbook, *Analyse des infiniment petits*, in 1696. The style and content of this book were influenced to a great extent by Johann (I) Bernoulli, who tutored the Marquis in the new mathematics in 1691-2. A distinguishing feature of the Marquis' textbook, when compared with later expositions of the calculus, was the geometric flavor of his many of his arguments. Through a comparison of his text with Bernoulli's lessons – which were discovered and published early in the 20th century – we seek to determine the extent to which the Marquis' geometric style was a reflection of his own approach and how much of it was due to Bernoulli's influence. (Received September 15, 2013)

1096-01-1304 **Jemma Lorenat***, jlorenat@sfu.ca. *Julius Plücker's Pure Geometry.*

In his 1956 *History of Analytic Geometry* (New York: Scripta Mathematica), Carl Boyer observed that the acclaimed nineteenth century analytic geometer, Julius Plücker (1801–1868), had first pursued pure geometry.

Boyer referred to Plücker's 1826 article "Théorèmes et problèmes, sur les contacts des sections coniques" published by Joseph-Diaz Gergonne (1771–1859) in his journal, the *Annales de mathématiques pures et appliquées.* Boyer hypothesized that Plücker was driven to analytic geometry following a plagiarism accusation by Jean-Victor Poncelet (1788–1867). However, as Boyer well knew though Poncelet did not, Gergonne had taken great eidtorial liberties with Plücker's manuscript. So much so that Plücker later described the published version as altered beyond recognition. The original article only appeared in 1904 within the *Mathematische Annalen.* This paper will reveal the curious history of Plücker's article, and employ the narrative to discuss the relationship between style, method, and results in the transmission of geometrical research during the early nineteenth century. (Received September 14, 2013)

1096-01-1336 **Alberto Cogliati***, Via Saldini 50, 20133 Milano, Milano, Italy. *On Jacobi's transformation theory of elliptic functions.*

Jacobi's *Fundamenta Nova Theoriae Functionum Ellipticarum* (1829) represents a landmark in the history of analysis; in it a systematic treatment of the emerging theory of elliptic functions was provided for the first time.

The main interpretative challenge set by the *Fundamenta* lies in Jacobi's transformation theory upon which the entire theoretical edifice of the treatise depends. Unfortunately, Jacobi did not convey any indication of how he attained his general formulae for rational transformations of elliptic functions. He limited himself to providing *a posteriori* verification of the validity of his claims.

The aim of the talk is precisely to describe the heuristic process by which Jacobi obtained these transformation formulae. The proposed historical reconstruction will hopefully shed new light upon the emergence in Jacobi's work of the inversion process of elliptic integrals of the first kind and thus of the elliptic function sinam$u$ itself. (Received September 15, 2013)

1096-01-1419 **Mohammad K. Azarian*** (azarian@evansville.edu), Department of Mathematics, University of Evansville, 1800 Lincoln Avenue, Evansville, IN 47722. *A Study of Risāla al-watar wa'l jaib ("The Treatise on the Chord and Sine").* Preliminary report.

The Treatise on the Chord and Sine is one of the three most significant mathematical achievements of Ghiyāth al-Dīn Jamshīd Mas'ūd al-Kāshī (d. 1429) dealing with the calculation of sine and chord of one-third of an angle with known sine and chord. Kāshānī completed this treatise sometime after 1424 (827 A.H.L.) and before 1427 (830 A.H.L.). Unfortunately, the original manuscript is lost. But, since the core part of this risāla was about the calculation of sine of one degree, several of Kāshānī's colleagues and successors have written commentaries in Arabic with the title, Risāla fī istikhrāj jaib daraja wāhida ("Treatise on the Determination of the Sine of One Degree"). Our discussion mainly will be based on commentaries by Salāh al-Dīn Mūsā Qādī zāde al-Rūmī (1360-1437) and Nizām al-Dīn 'Abd al-'Alī al-Bīrjandī (d. 1528). There are two parts in the calculation of sine of one degree. First, Kāshānī applied Ptolemy's theorem to an inscribed quadrilateral to obtain a cubic equation, and then he used, for the first time, an ingenious iteration method to calculate sine of one degree to 17 correct decimal digits as a root of this cubic equation. (Received September 15, 2013)

1096-01-1482 **Sylvia M Nickerson*** (s.nickerson@utoronto.ca). *Mathematics for the World: Publishing Mathematics and the International Book Trade, Macmillan and Co. 1870-1910.*

Victorian publisher Macmillan and Co. published a large number of mathematical authors. This list includes G. Boole, J. Venn, I. Todhunter, C. Dodgson, W. Spottiswoode, W. K. Clifford, P. G. Tait, W. Thomson, J. C. Maxwell and G. G. Stokes. Besides academic books on mathematical subjects, Macmillan published mathematical textbooks for schools and colleges. Although Alexander Macmillan once remarked, in reference to a book about particle dynamics, that books on "high" subjects made no money, "low" books on geometry, algebra and arithmetic proved highly profitable for the company.

This paper looks at how Macmillan selected, produced, advertised and sold their mathematical books, and examines how financially successful these books were for their authors and the publisher. Macmillan's most successful textbooks on mathematical subjects were produced into the hundreds of thousands, even millions of copies, and distributed to English speaking markets in the United Kingdom, Canada, the United States, Australia, India and elsewhere. Not only did the sale of these books profit their publisher, but the image of mathematics contained in them spread a specific impression of the subject to students in several countries around the world. (Received September 15, 2013)

1096-01-1503 **Shigeru Masuda*** (hj9s-msd@asahi-net.or.jp), 56-5-202 Yoshida-Izumidono-chou, Sakyo-ku, Kyoto, 6068301, Japan. *Fourier's Equations of Heat Motion in Fluid and Boltzmann's Transport Equations.*

Our motivation owes to our interest in the mathematical physics in classical fluid dynamics including the heat theory. Owing to the arrival of continuum theory, many works of mathematical physics are introduced, such as heat theory and heat diffusion equations and communication theory that are based on the continuum. In the current of formularizing process of the fluid dynamics, Euler, Navier, Poisson, Cauchy and Stokes struggle to deduce the wave equations and fluid dynamics equations. Fourier connects the heat communication theory with the Euler's equations of incompressible fluid dynamics and proposes the equation of heat motion in fluid, which sheds a light on fluid-thermodynamics. Sir W. Thomson stands by the British academy to introduce Fourier's theories. The gas theorists like Maxwell, Boltzmann construct thermodynamics equations based on the concept of molecular collision, hinted by Fourier's communication theory and heat equations of motion in fluid. Especially, Boltzmann brings the concepts of entropy and probability of molecule in his transport equations. Schrödinger pays attention to the eigenvalue problem hinted by Kepler problems and makes his equations. We document contributions of classical mechanics to quantum mechanics. (Received September 17, 2013)

1096-01-1528 **June E. Barrow-Green*** (june.barrow-green@open.ac.uk), Faculty of Mathematics, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom. *The three-body problem.*

In 1904, Edmund Taylor Whittaker described the three-body problem as 'the most celebrated of all dynamical problems', noting that since 1750 more than 800 memoirs, many of them authored by the greatest mathematicians, had been published on the subject. As well as being mathematically engaging, the problem is of practical importance for celestial mechanics which accounts in large part for its popularity. In this talk, I shall describe some of the progress made on the problem during the 19th and early 20th centuries, including contributions of both mathematicians and mathematical astronomers. (Received September 16, 2013)

1096-01-1531 **Erika Luciano*** (erika.luciano@unito.it), via Carlo Alberto 10, I10123 Torino, Torino, Italy. *The teaching of mathematics during the Fascism dictatorship through the lens of the educational journals.*

The exam of some educational journals, such as the Bollettino di Matematica and Schola et Vita, will allow us to illustrate the main problems and debates on scientific education in Italy during the years 1923-1943. The choice of this particular lens of historiographic analysis will also permit us to establish if and to what extent the international partnerships and the circulation of information and materials concerning mathematical instruction survived, notwithstanding the oppressive restrictions imposed from the fascism dictatorship. (Received September 16, 2013)

1096-01-1544 **mustafa r.s. kulenovic***, university of rhode island, kingston, RI 02881. *Sharaf al-Tusi (1135-1213): the grandfather of Differential Calculus ?* Preliminary report.

We argue that Sharaf al-Tusi (1135-1213) can be considered as grandfather of Differential Calculus. Without using the coordinate system he made perfect use of the derivative of cubic polynomial to find the necessary and sufficient conditions for cubic equation to have one, two or three real roots. In doing so he discovered the discriminant of the cubic equation. His method can be easily extended to quartic equation to obtain the necessary and sufficient conditions for quartic equation to have one, two, three or four real roots. These conditions are of great importance in contemporary stability theory of differential and difference equations. (Received September 16, 2013)

1096-01-1605 **Joseph W Dauben*** (jdauben@att.net), Herbert H. Lehman College, The City University of New York, 250 Bedford Park Blvd. West, New York, NY 10468. *The Actual Infinite and Infinitesimals in the 19th Century—Boon or Bane?*

Without trying to rationally reconstruct a view of either the infinite or infinitesimals made rigorous in the 20th century by Zermelo-Frankel set theory or Abraham Robinson's nonstandard analysis, the problem of continuity is fundamental to the problems in analysis faced by those who sought to consider the problem not in terms of "limit-avoidance" as Cauchy's approach has been described by Ivor Grattan-Guinness, but by embracing the concept of infinitesimals, although mathematicians who did so in the late nineteenth century adopted a number of different perspectives. Among the luminaries of Baltimore at the newly-founded Johns Hopkins University was the mathematician-philosopher Charles Sanders Peirce. He held rather controversial views in many areas, including mathematics and the twin problems of the infinite and infinitesimals in particular. As for infinitesimals, Peirce approached the subject in terms of logic and the syllogism of transposed quantity, which led him to embrace infinitesimals. Mathematicians were more conflicted; a few accepted them, others vehemently rejected them. Focusing on the contributions made du Bois Reymond, Cantor, Stolz, Veronese, and Peirce, the different views maintained by mathematicians at the time will be evaluated on their own terms. (Received September 16, 2013)

1096-01-1910 **William Alfred Massey*** (wmassey@princeton.edu), ORFE Department, Sherrerd Hall, Princeton University, Princeton, NJ 08544. *Some of David Blackwell's Reflections on the Work of David Blackwell (1919-2010).* Preliminary report.

This talk presents one of David Blackwell's favorite results. We also briefly discuss his legacy to both the field of statistics and under-represented minority researchers in the mathematical sciences. (Received September 16, 2013)

1096-01-1920 **William Alfred Massey*** (wmassey@princeton.edu), ORFE Department, Sherrerd Hall, Princeton University, Princeton, NJ 08544. *Conferences for African-American Researchers in the Mathematical Sciences (CAARMS).* Preliminary report.

This year the 20th Conference for African-American Researchers in the Mathematical Sciences, or CAARMS20 for short, will take place. This talk will discuss the two-decade evolution of the conference and its impact on the African-American mathematical community. (Received September 16, 2013)

1096-01-1949 **Idris Stovall*** (istovall@math.upenn.edu), Department of Mathematics, David Rittenhouse Laboratory, 209 South 33rd Street, Philadelphia, PA 19104-6395. *The Influence of John Robert Kline on African-American Mathematics.* Preliminary report.

John Robert Kline (1891–1955) was a professor of mathematics at the University of Pennsylvania from the years 1920 to 1955. During that time he supervised 19 Ph.D. theses. It turns out that three of his Ph.D. students were African-American. They are Dudley Weldon Woodard in 1928, who is also the second African-American to receive a Ph.D in mathematics. The third one ever is another student of Kline's, William Waldron Shieffelin Claytor in 1933. Kline's last African-American student was George Hench Butcher, Jr. in 1955. All three of them went on to play major leadership roles in the Mathematics department at Howard University. (Received September 16, 2013)

1096-01-1998 **Jonathan David Farley*** (jonathan.farley@morgan.edu), Department of Mathematics, Morgan State University, 1700 E. Cold Spring Lane, Baltimore, MD 21251. *The Adventures of Lee Lorch: What Two New Books by Barrett Brown, Edward Sebesta and Euan Hague Say about Vanderbilt University and Black Mathematicians.*

Five decades before a black mathematician at Vanderbilt University fled Nashville under cover of darkness, making his way to the AMS meeting in Baltimore after receiving numerous death threats, Lee Lorch, a mathematician at the historically black Fisk University, tried to bring a group of black mathematicians to Vanderbilt's campus for an MAA talk. They were barred from attending. The speaker, Saunders Mac Lane, president of the MAA, spoke anyway, because he didn't want to be rude to Vanderbilt, he said.

In the book "University Presidents As Moral Leaders," Gordon Gee, the former leader of Vanderbilt University, described groups that celebrated the pro-slavery Confederacy as "old friends".

Two new books, one by Barrett Brown and another by Edward Sebesta and Euan Hague, are coming out about Vanderbilt University and this peculiar history. (Received September 17, 2013)

1096-01-2215 **Eileen Magnello*** (meileenmagnello@aol.com), Dept. of Science and Technology Studies, University College London, Gower Street London WC1 6BT, UK, London, United Kingdom. *Florence Nightingale's Statistical Innovations.*

Florence Nightingale's most influential statistical ideas and work grew out of an intellectually stimulating childhood, a talent for academic excellence and a life-long propensity to organise quantitative information that began when she was a child. Her statistical thinking, which coalesced with many of her Victorian religious ideas, fuelled the many prodigious statistical projects she undertook and the innovative statistical graphs she developed. A practitioner of evidence-based medicine she used her extensive statistical data, much of which involved calculating death-rates, to produce major health reforms in military and civilian hospitals, usually with the full support of the government. This paper will examine the way in which Nightingale's religious thinking shaped her development as a statistician, which enabled her to establish the necessary and essential nursing and hospital reforms that modernised nursing in the mid- to late-Victorian period. (Received September 17, 2013)

1096-01-2279 **William A Hawkins JR***, bhawkins@maa.org. *The Life of David Harold Blackwell, Inspiration for Generations.*

The many accomplishments of Dr. David H. Blackwell are especially inspiring to minority mathematicians. The talk will focus on less well-known details of his biography and their impact on his work. (Received September 17, 2013)

1096-01-2315 **Margaret H. Dean*** (mdean@bmcc.cuny.edu), mdean@bmcc.cuny.edu, **Margaret Karrass**, mkarrass@bmcc.cuny.edu, and **Marianna Bonanome**. *History of Combinatorial Group Theory in the US, Mid-Twentieth Century, a preliminary report.* Preliminary report.

Modern group theory can be said to have been born at the beginning of the twentieth century. As with many fields in mathematics, World War I caused a hiatus in the study of group theory. In 1932, Wilhelm Magnus solved the word problem for one-relator groups, and combinatorial group theory blossomed from the 30's through the 60's, laying the foundation for today's research in the areas of geometric and probabilistic group theory, as well as public key cryptography and group theory. We will talk about some of the personalities involved and the advances they made in group theory during the mid-twentieth century. (Received September 17, 2013)

1096-01-2621 **Charlotte K Simmons*** (cksimmons@uco.edu) and **Jesse W. Byrne** (jbyrne@uco.edu). *Richard Courant: "Gottingen is Here".* Preliminary report.

As many as 144 German-speaking mathematicians have been listed who were forced to leave their positions at German institutions following the 1933 Law for the Restoration of the Professional Civil Service. The "great migration of the 1930's" is said to have shifted the center of the mathematical world from Germany to the United States. Numbered among these emigrants is Richard Courant, who was "absolutely inexhaustible" and relentlessly pursued his dream of building an institute for advanced training in mathematics at New York University for nearly two decades. By 1958, the Courant Institute, which began as a suite of rooms in a girls' dormitory, was described as the "national capital of applied mathematical analysis." In this talk, we will discuss Courant's efforts to bring his experience in Gottingen to bear upon the state of science in America, as well as how he and other immigrants impacted mathematics in America during this important chapter in our history. (Received September 17, 2013)

1096-01-2683 **Maryam Vulis*** (maryam@vulis.net), 67-67 Burns St, Forest Hills, NY 11375. *History of the Ideas that Led to Math-Based Currencies.*

Math-based currencies (Bitcoin and less famous alt-coins) appear prominently in the news. The elegant mathematical machinery of Bitcoin provides insightful examples for teaching cryptography and is more fully appreciated when examined in its historical context This presentation explores the origins of the mathematical ideas that culminated in practically usable math-based currencies. We trace the development of cryptographic protocols from the 1933 Bohr-Heisenberg mental poker game to the 1979 "other" RSA paper to the 1995 David Shaum's e-Cash and other milestones.

Truly, Bitcoins stand on the shoulders of giants. (Received September 17, 2013)

1096-01-2746 **Adriana Monica Solomon*** (monicadriana.solomon@gmail.com), Department of Philosophy, University of Notre Dame, 100 Malloy Hall, Notre Dame, IN 46556. *The Correspondence Between Cantor and Dedekind: the case for a surprising dialogue between mathematicians, historians, and philosophers.*

A recent panel for the MAA presents an exchange between educators within mathematics about the types of mathematical knowledge they encountered. While the discussion is relevant to curriculum guidelines and methods to improve teaching, here I connect the discussion to the common reaction of surprise as a crucial element for learning mathematics. The ability to be surprised in mathematics is essential to a process of reverse engineering by which we relate ourselves to other people's expectations and interests. In the main part of my paper, I show how a historical example (the correspondence between Cantor and Dedekind) should make us more interested in developing types of mathematical knowledge that admit of multiple epistemic stances with respect to some result or some proof. Drawing inspiration from Wittgenstein's later works, I show that there are types of mathematical knowledge that make no mystery of someone knowing something, but find it hard to believe. My contribution is part of an interdisciplinary approach that can provide philosophers and mathematicians with new perspectives on old questions, as well as pointing to further questions that are "worthy of philosophical attention." (Leng, Passeau & Potter (2007), p. 15). (Received September 18, 2013)

03 ► Mathematical logic and foundations

1096-03-110 **Jeremy Avigad*** (avigad@cmu.edu), Carnegie Mellon University, Pittsburgh, PA 15213. *Formal verification, interactive theorem proving, and automated reasoning.*

In computer science, the phrase "formal verification" refers to the use of formal methods to verify the correctness of hardware and software with respect to a specification, and, more generally, to the use of formal methods to verify mathematical claims. "Interactive theorem proving" is one important approach, in which interactive proof assistants are used to construct formal axiomatic proofs. Although most contemporary work in formal verification is focused on industrial applications, the field promises to have a long-term impact on the development of mathematics as well, with recent developments such as Thomas Hales' *Flyspeck* project, Georges Gonthier's verification of the Feit-Thompson Odd-Order Theorem, and Vladimir Voevodsky's *Univalent foundations* project.

Formal verification relies crucially on core ideas, methods, and results from mathematical logic, drawing on foundational languages and frameworks, decision procedures, and twentieth-century proof-theoretic and model-theoretic notions. Progress in interactive theorem proving in particular now requires a deeper understanding of mathematical language, method, and proof. In this talk, I will survey the state of the art and explore the logical and conceptual issues that arise. (Received September 09, 2013)

1096-03-199 **Joel David Hamkins*** (jhamkins@gc.cuny.edu), The CUNY Graduate Center, Mathematics, 365 Fifth Avenue, New York, NY 10016. *Embeddability amongst the countable models of set theory.*

A surprisingly vigorous embeddability phenomenon has recently been uncovered amongst the countable models of set theory. In particular, embeddability is linear: for any two countable models of set theory, one of them is isomorphic to a submodel of the other. Indeed, every countable model of set theory, including every well-founded model, is isomorphic to a submodel of its own constructible universe, so that there is an embedding $j : M \to L^M$ for which $x \in y \iff j(x) \in j(y)$. The proof uses universal digraph combinatorics, including an acyclic version of the countable random digraph, which I call the countable random $\mathbb{Q}$-graded digraph, and higher analogues arising as uncountable Fraïssé limits, leading to the hypnagogic digraph, a set-homogeneous, class-universal, surreal-numbers-graded acyclic class digraph, closely connected with the surreal numbers. Commentary concerning this talk can be made on my blog at http://jdh.hamkins.org/plenary-talk-asl-jmm-baltimore-january-2014/. (Received August 15, 2013)

1096-03-390 **Damir D Dzhafarov*** (damir@math.uconn.edu), Department of Mathematics, University of Connecticut. *New directions in reverse mathematics.*

Mathematics today benefits from having "firm foundations", i.e., a system of axioms sufficient to prove the theorems we care about. But given a particular theorem, can we specify precisely which axioms are needed to prove it? This is a natural question, and also an ancient one. Reverse mathematics provides a modern approach to this kind of question. A striking fact repeatedly demonstrated in this area is that the vast majority of mathematical propositions can be classified into just five main types, according to which set-existence axioms are needed to carry out their proofs. But more recently, a growing number of principles falling outside this classification have emerged, whose logical strength is more difficult to understand. These turn out to include many important mathematical results, such as various combinatorial problems related to Ramsey's theorem, and several equivalents of the axiom of choice. I will discuss some of these "irregular" principles, and some new approaches arising from trying to understand why their strength is so different from that of most other theorems. In particular, this investigation reveals new connections between different mathematical areas, and exposes the complex combinatorial and algorithmic structure of mathematics as a whole. (Received September 01, 2013)

1096-03-417 **Steve Awodey*** (awodey@cmu.edu). *Recent work in Homotopy Type Theory.*

Homotopy type theory is a homotopical interpretation of a system of formal logic, providing a system of foundations with intrinsic homotopical content and a computational implementation. It forms the basis of the Univalent foundations program, which was the subject of a recent special year at IAS. In this survey talk, I will show how to compute some homotopy groups of spheres in homotopy type theory, including $\pi_3(S^2)$. These new logical proofs of classical theorems from algebraic topology make essential use of the new ideas of higher inductive types and the Univalence axiom. (Received September 03, 2013)

1096-03-420 **Uri Andrews** and **Isaac Goldbring*** (isaac@math.uic.edu), Department of Mathematics, Statistics, and CS, Science and Engineering Offices (M/C 249), 851 S. Morgan St., Chicago, IL 60607-7045, and **H. Jerome Keisler**. *A survey on Keisler randomizations.*

Given a first-order structure $\mathcal{M}$, Keisler introduced the structure $\mathcal{M}^R$, the *randomization of* $\mathcal{M}$, which essentially consists of the space of $\mathcal{M}$-valued random variables. Initially the randomized structure was considered in first-order logic, but with the help of Itaï Ben Yaacov, the theory of randomizations was placed into the correct framework of continuous logic.

In this talk, I will survey some of the known results concerning the model-theoretic properties of randomizations of structures, showing how the randomization process often preserves many of the model-theoretic properties of the original structure.

I will end by reporting on some recent work, joint with Uri Andrews and H. Jerome Keisler, where we explore definability and various notions of independence in randomizations. (Received September 03, 2013)

1096-03-430 **Vincent N Guingona*** (guingona.1@nd.edu), University of Notre Dame, Department of Mathematics, 255 Hurley, Notre Dame, IN 46556. *On VC-minimal fields.*

In this talk, I discuss recent work on classifying VC-minimal algebraic theories. For example, I look at VC-minimal fields. Using techniques developed by J. Flenner and myself, I show that all VC-minimal ordered fields are real closed. Furthermore, work of K. Krupinski and A. Pillay can be used to show that all VC-minimal stable fields are algebraically closed. (Received September 03, 2013)

1096-03-530 **Alexander S. Kechris***, Department of Mathematics, California Institute of Technology, Pasadena, CA 91125. *Amenability, unique ergodicity and random orderings.*

I will discuss the phenomenon of unique ergodicity for automorphism groups of countable structures and its connection with finite Ramsey theory and random orderings on finite structures (joint work with Omer Angel and Russell Lyons). (Received September 05, 2013)

1096-03-765 **Kai Maeda*** (kai.maeda@oist.jp). *Degree spectra of rack.* Preliminary report.

The theory of racks is a relatively new subject in algebra, which has origins in knot theory and has strong connections with group theory. H. Conway and G. Wraith were first to study "wracks," which were later termed "racks" by R. Fenn and C. Rouke. A rack is a structure Q with a single binary operation $*$ satisfying the following two axioms:

(1) For every x, y, z, we have $(x * y) * z = (x * z) * (y * z)$, and

(2) For every x and y, there is a unique z such that $z * x = y$.

The operation $*$ is not necessarily associative nor commutative. We study computability theoretic properties of racks. The Turing degree spectrum of a rack Q is the set of all Turing degrees of isomorphic copies of Q. We investigate when these degree spectra are upper cones in the upper semilattice of the Turing degrees. (Received September 10, 2013)

1096-03-774 **Sebastian Wyman*** (swyman@aurora.edu), Aurora University, Aurora, IL 60506. *Partially computable functions and symbolic dynamics.*

In 2008, Cenzer, Dashti, and King explored the properties of certain subshift under various descriptions and levels of complexity. Specifically, they show that Π^0_1 subshits are always the result of forbidding some ce set of words from the underlying tree and that the decidable subshits are exactly those that result from examining the itineraries of some computable dynamical system. In 2013, Wyman defined conservatively approximable functions and a strengthening of those to get a similar result for Π^0_1 subshifts and itineraries of dynamical systems. These functions are total functions, with a complicated definition. We will show the connection between decidable subshits and the set of forbidden words; specifically, the set must be computable and its compliment must be a subsimilar tree with no dead-ends. Additionally, we will present and discuss the connection between partial computable functions and Π^0_1 subshits via intineraries. (Received September 10, 2013)

1096-03-881 **Sam Buss** and **Mia Minnes*** (minnes@math.ucsd.edu). *New investigations in probabilistic strategies for algorithmic randomness.*

Probabilistic betting strategies provide a method of characterizing algorithmically random sequences, including Martin-Lof random sequences and (partial) computably random sequences. We generalize probabilistic betting strategies to allow probabilistic moves at every step, not just at betting steps; we also consider restricting randomness to binary choices (or, "coin flips"). We prove that these modifications do not change the strength of probabilistic betting strategies. We give a new proof of the separation of Martin-Lof randomness and partial computable randomness using probabilistic betting strategies. (Received September 10, 2013)

1096-03-925 **Reed Solomon*** (david.solomon@uconn.edu). *Computability in Cantor space and in orderings of an abelian group.*

If G is a countable infinite rank torsion-free abelian group, then the space of orders on G is classically homeomorphic to Cantor space. However, the space of orders on an computable torsion-free abelian group is more computationally restricted than a general Π^0_1 class which is classically homeomorphic to Cantor space. This talk will survey some of the known results in this area including connections between computing a basis and computing an order which have been recently refined by Caleb Martin. (Received September 11, 2013)

1096-03-933 **Timothy H. McNicholl*** (mcnichol@iastate.edu), Department of Mathematics, Iowa State University, 396 Carver Hall, Ames, IA 50011. *How to hide from a nanobot.*

We consider two classes of points in the plane. The first consists of all points that can be reached by a nanobot (which we model by a point in the plane) that is required to traverse a curve of finite length. Mathematically, this is the set of all points in the plane that lie on a computable planar curve of finite length. This class of points has been characterized by Gu, Lutz, and Mayordomo. The second class consists of all points that can be reached by a nanobot that is prohibited from backtracking. Mathematically, this is the set of all point that lie on a curve that is the image of a computable and injective map on $[0, 1]$; that is, a computable arc. We show that neither of these classes is contained in the other. The methods employed are a mixture of ideas from classical analysis and topology, the finite-injury method, and algorithmic randomness. In particular, it is shown that every Martin-Löf random point lies on a computable arc. (Received September 11, 2013)

1096-03-963 **Will Boney*** (wboney@andrew.cmu.edu), Dept of Mathematical Sciences, Carnegie Mellon University, 5000 Forbes Ave, Pittsburgh, PA 15232, and **Rami Grossberg**. *Forking in Abstract Elementary Classes.*

We outline work to develop an a forking-like relation over models, for Abstract Elementary Classes under mild assumptions (stability, tameness, type-shortness, and existence). This replaces and extends a much more complicated notion of Shelah called good λ-frame. We describe the basic properties of this nonforking and discuss the strength of the assumptions. We conclude with a discussion of large cardinals and an application to local character and the uniqueness of limit models. (Received September 11, 2013)

1096-03-1066 **Yun Lu*** (lu@kutztown.edu), Mathematics Department, Kutztown University of PA, Kutztown, PA 19530. *Strong Finite Submodel Property of Countable Categorical Graphs.*

This talk investigates the application of Borel-Cantelli Lemma to prove the Strong Finite Submodel Property of countable categorical graphs. A countable structure Γ is said to have the Strong Finite Submodel Property if Γ can be written as a union of increasing substructures Γ_i where $|\Gamma_i| = i$, and for all sentences ϕ true of Γ there is an N such that $i > N$ implies ϕ is true of Γ_i.

The Borel-Cantelli Lemma was applied by Simon Thomas in 1996 to simplify a complicated model theoretic proof of the Strong Finite Submodel Property of random hypergraphs. In this talk we will discuss Thomas' approach and our results on the Strong Finite Submodel Property of random bipartite graphs. (Received September 12, 2013)

1096-03-1073 **Kelty Allen*** (kelty@math.berkeley.edu). *Martin-Löf random Brownian motion.*

Brownian motion as studied in probability theory gives rise to a measure on a function space, known as Wiener measure. One can study the Martin-Löf random elements of a space with respect to this measure; this is known as Martin-Löf random Brownian motion. We will cover some of the "almost surely" results from classical probability theory that hold for Martin-Löf random Brownian motion, and discuss some of the many interesting computability theoretic properties of such paths. (Received September 12, 2013)

1096-03-1129 **Dan E Willard*** (dew@cs.albany.edu), Room Li67A, Computer Science Department, University at Albany, 1400 Washington Avenue, Albany, NY 12222. *An Epistemological Summary of the Significance of Self-Justifying Axiom Systems.*

We have published a series of papers, since 2001, about generalizations and boundary-case exceptions for the Second Incompleteness Theorem, including four papers in the JSL and two in APAL. The current talk and the accompanying report,at the web site http://arxiv.org/abs/1307.0150, shall offer a summary of this subject, accessible to a broad audience with a diverse range of backgrounds.

It is evident that the Second Incompleteness Theorem is a widely encompassing result that has many generalizations. It clearly allows for the existence of exceptions to it only under formalisms that contain some type of weakness, that allows them to escape its scope. These exceptions are, nevertheless, of interest because it is problematic to explain how human beings are able to gather the necessary psychological drive and motivation to cogitate without using, at least, some non-orthodox notion of self consistency. The current talk (as well as the reports listed in the preceding paragraph) will provide a summary, comprehensible to a broad audience, about the types of partial boundary-case exceptions that the Second Incompleteness Theorem permits to feasibly exist. (Received September 15, 2013)

1096-03-1138 **Victor A. Ocasio*** (vocasiog@nd.edu). *Computability in the class of Real Closed Fields.*
The class of Real Closed Fields (RCF) is known to have very nice model theoretic properties, among them o-minimality and quantifier elimination. In our work, we consider some non-elementary subclasses of RCF and explore their computability theoretic properties. We locate the class of Archimedean Real Closed Fields using Turing computable embeddings and compare it with other non-elementary subclasses of RCF. We also explore relative categoricity and show that under some conditions one can obtain a sharp result on the complexity of the relative categoricity of a real closed field that is constructed using a linear order as an oracle. (Received September 13, 2013)

1096-03-1167 **Erin Kathryn Carmody***, carmody.erin@gmail.com. *Large Cardinals: Killing Them Softly.*
I shall introduce the killing-them-softly phenomenon in the large cardinal hierarchy. I will give a survey of results showing how to kill a large cardinal by forcing while preserving as many of its weaker large cardinal properties as possible. There are a variety of instances of large cardinals which can be killed softly, in this sense, and I will describe the forcing notions which do so. (Received September 13, 2013)

1096-03-1184 **Alexander Berenstein***, Universidad de los Andes, Cra 1 nro 18 A- 10., Bogota, Colombia, and **Itaï Ben Yaacov** and **Ward Henson**. *Model theory of probability spaces.*
In this talk we will discuss how to study the measure algebra of a probability space from the point of view of continuous model theory. This theory turns out to be very well behaved, it is ω-stable and separably categorical. Conditional distributions arise naturally from the model theoretic perspective as canonical bases. We will study conditional distributions and show that for these objects the logic topology agrees with weak convergence. Finally we will show how to interpret and prove model theoretically some results of Berkes and Rosenthal dealing with sequences of random variables. (Received September 13, 2013)

1096-03-1208 **Johanna Franklin**, Department of Mathematics, University of Connecticut, Storrs, CT , and **Henry P Towsner***, Department of Mathematics, University of Pennsylvania, Philadelphia, PA 19143. *Algorithmic Randomness in Ergodic Theory.*
The Birkhoff pointwise ergodic theorem says that in a dynamical system, the ergodic averages

$$\frac{1}{N}\sum_{i<N} f(T^i x)$$

converge to a limit for all x outside a set of measure 0. From the perspective of algorithmic randomness, it is natural to place computability restrictions on T and f and investigate the nature of the exceptional points.

On the dynamical system side, the problem depends significantly on whether the system is ergodic or not. (That is, whether the space can be decomposed into two disjoint sets of positive measure so that, up to measure 0, the sets are constant under T.) The relationship between ergodic and non-ergodic systems turns out to be closely analogous to the relationship between computable and computably enumerable functions. (Received September 13, 2013)

1096-03-1276 **Gregory Igusa*** (gigusa@nd.edu). *The Generic Degrees of Coarsely Computable Reals.*
A real is *generically computable* if there is an algorithm which halts almost everywhere (in the sense of limiting density 1) and which correctly computes the real wherever it halts. This definition is inspired by the phenomenon from complexity theory, where a generic (ie, typical) instance of a problem might be much easier to solve than the most difficult instances of the problem. A real is *coarsely computable* if there is an algorithm which halts everywhere, and which correctly computes the real almost everywhere.

If we attempt to study the degree structure for generic reducibility, we are forced to consider oracles which do not always halt, and this causes the reducibility to be very difficult to work with, and in fact, to be $\mathbf{\Pi^1_1}$-complete. The generic degrees of the coarsely computable reals display a number of interesting properties, provide a good vantage point for understanding the structure of the generic degrees, and also provide us with a an interesting characterization of the hyperarithmetical Turing degrees in terms of generic reduction. (Received September 14, 2013)

1096-03-1363 **Katalin Bimbó*** (bimbo@ualberta.ca), University of Alberta, Department of Philosophy, 2–40 Assiniboia Hall, Edmonton, Alberta T6G 2E7, Canada, and **J. Michael Dunn** (dunn@indiana.edu), School of Informatics and Computing, Indiana University, 901 East 10th Street, Bloomington, IN 47408. *Combinatory inhabitants of $R_{\to}$ theorems extracted from sequent calculus proofs.*

A match between certain combinators and some implicational formulas goes back to the work of H. B. Curry in the 1940s. What is known nowadays as the implicational fragment of the relevance logic R was formulated as an axiom system by A. Church in the early 1950s. The so-called Curry–Howard isomorphism is well-known for the implicational fragment of intuitionistic logic and $\{\mathsf{S},\mathsf{K}\}$, and it has been extended to certain relevance logics and other combinatory bases. This correspondence usually links proofs in natural deduction or axiomatic calculi to inhabitants of the theorems proved.

We proved in two papers (*Notre Dame Journal of Formal Logic* 53 (2012): 491–509; *Journal of Symbolic Logic* 78 (2013): 214–236) that pure ticket entailment is decidable; a core component of our proof was the sequent calculus $LT_{\to}^{\textcircled{t}}$, which is an extension of $LT_{\to}^{t}$. Then we went on (in Bimbó and Dunn (2013b)) to describe an algorithm to create a $\mathsf{BB'IW}$-inhabitant from a proof of a theorem of $T_{\to}$ in the sequent calculus $LT_{\to}^{t}$. In this talk, we adopt a similar approach, and we show how to extract concrete $\mathsf{BB'IWT}$ inhabitants from sequent calculus proofs of $R_{\to}$ theorems. (Received September 15, 2013)

1096-03-1364 **Valentina Harizanov*** (harizanv@gwu.edu), Department of Mathematics, Goverment Hall 220, The George Washington University, Washington, DC 20052. *Notions of degree spectra.*

We give an overview of earlier results and recent developments in our investigation of the Turing degree spectra of structures, relations, automorphisms, and sets of relations. The degree spectrum of a countable structure $\mathcal{A}$ is the set of all degrees of the atomic diagrams of the isomorphic copies of $\mathcal{A}$. The degree spectrum of an additional relation R on a computable structure $\mathcal{B}$ is the set of Turing degrees of the images of R under all isomorphisms from $\mathcal{B}$ onto computable structures. While many degree spectra of relations have upper bounds, all nontrivial degree spectra of structures are closed upward in the Turing degrees. The automorphism degree spectrum of a computable structure is the set of degrees of its nontrivial automorphisms. While no automorphism degree spectrum consists of exactly two incomparable degrees, various sets of Turing degrees, including many upper cones, can be realized as automorphism degree spectra. We also consider a family of natural relations on a computable structure and investigate their degree spectrum. Our main example is the set of orders on a computable group. (Received September 15, 2013)

1096-03-1373 **Maryanthe Malliaris***, Department of Mathematics, University of Chicago, 5734 S University Avenue, Chicago, IL 60637. *The asymptotic structure of unstable theories.*

The stable theories are of great significance to model theory, but there are comparatively few of them. To see gradations in complexity among the unstable theories from a more uniform point of view, ultrapowers are very useful, notably in the guise of Keisler's order. This order uses the criterion of saturation of regular ultrapowers to outline a large scale model-theoretic program of comparing the complexity of theories. Ultrapowers give a perspective in which local noise is smoothed out and the nature of the significant jumps in the complexity of pseudofinite structure can be more clearly seen. Very recent progress on this order, due to Malliaris and to Malliaris and Shelah, lays the groundwork for new dividing lines among the unstable theories, having no analogue in the stable case. This talk will present some highlights of this recent work from a model-theoretic point of view. (Received September 15, 2013)

1096-03-1435 **Jack H. Lutz*** (lutz@cs.iastate.edu), Iowa State University, Department of Computer Science, 226 Atanasoff, Ames, IA 50011. *Points and Lines, Randomness and Dimension.*

This talk will discuss recent results on the randomness and dimensions of points on lines in Euclidean space. (Received September 15, 2013)

1096-03-1472 **Stephen Flood*** (stephen.flood@uconn.edu). *Long Graph Decompositions.* Preliminary report.

The theory of simplicial graph decompositions studies the infinite graphs that can be built from a sequence of irreducible subgraphs which are attached together at complete subgraphs. Our focus will be on the minimum length of these decompositions.

A result of Diestel says that every countable simplicial tree decomposition can be rearranged to have length at most ω. We show that no such ordinal bound can be found for the lengths of non-tree decompositions. More generally, we show that for each ordinal σ, there is a decomposable graph whose shortest simplicial decomposition has length exactly σ. (Received September 15, 2013)

1096-03-1534 **Daniel Turetsky*** (dturets@gmail.com), Kurt Gödel Research Center, Währinger Strasse 25, 1090 Wien, Austria. *SJT as an analog of K-triviality.*

SJT is a natural ideal strictly contained within the ideal of K-trivial degrees. There are a number of results connecting the K-trivials with notions of randomness. For example, there is the covering problem, which states that every K-trivial is computable from a difference random. Many of these results have analogs for SJT; for example, every SJT is computable from a Demuth random. I will present SJT and its parallels with K-triviality. (Received September 16, 2013)

1096-03-1554 **Christopher P Porter*** (cp@cpporter.com), LIAFA, Université Paris Diderot - Paris 7, Case 7014, 75205 Paris Cedex 13, France, **Laurent Bienvenu** (laurent.bienvenu@computability.fr), LIAFA, Université Paris Diderot - Paris 7, Case 7014, 75205 Paris Cedex 13, France, and **Antoine Taveneaux** (antoine.taveneaux@calculabilite.fr), LIAFA, Université Paris Diderot - Paris 7, Case 7014, 75205 Paris Cedex 13, France. *Randomness, Probability, and Computation.* Preliminary report.

In this talk, I will discuss recent joint work with Laurent Bienvenu and Antoine Taveneaux on the limitations of probabilistic computation in the context of algorithmic randomness. More specifically, I will highlight our work on deep Π^0_1 classes, where a Π^0_1 class $\mathcal{P}$ (i.e., an effectively closed subclass of 2^ω) is *deep* if it is maximally difficult to produce an initial segment of a member of $\mathcal{P}$ via any probabilistic algorithm (understood as a Turing machine equipped with an algorithmically random oracle). I will lay out some basic properties of deep Π^0_1 classes and will provide a number of examples from computability theory. (Received September 16, 2013)

1096-03-1603 **Carl Mummert***, Department of Mathematics, 1 John Marshall Drive, Huntington, WV 25755, and **Alaeddine Saadaoui** and **Sean Sovine**. *The modal logic of Reverse Mathematics.* Preliminary report.

Reverse Mathematics is a research program in mathematical logic that studies the implications between well-known mathematical theorems. The two main kinds of results are that a theorem S implies a theorem T, or that a theorem S does not imply a theorem T, relative to a system of basic axioms. We establish a theoretical foundation for automated theorem proving of Reverse Mathematics results by characterizing the logic of these implications and non-implications. The implication relationship in Reverse Mathematics is distinct from the material conditional, because the claim that "S materially implies T" may have different truth values in different models, while the Reverse Mathematics result that S implies T shows that every model of the basic axioms that satisfies S also satisfies T. This implication relation between theorems is most naturally viewed as a strict implication as in modal logic. The logic we obtain, which we call s-logic, is a fragment of the classically studied modal logic known as S5. We present complete sets of inference rules for s-logic and two important fragments (Received September 16, 2013)

1096-03-1680 **Michael Chris Laskowski***, Department of Mathematics, University of Maryland, College Park, MD 20742. *Algebraic existential quantifiers.*

Call a formula $\psi(\overline{y})$ *algebraically existential* if it is equivalent to $\exists\overline{x}\varphi(\overline{x},\overline{y})$, where φ is quantifier free and there is a uniform bound k_φ such that $\varphi(\overline{x},\overline{b})$ has at most k_φ solutions for every $\overline{b}$ from every model of the theory. We discuss a variant of model completeness in which every formula is equivalent to a boolean combination of such formulas. Examples of theories with this property include the elementary diagrams of arbitrarily colored symmetric graphs, whose valence is uniformly bounded by some integer. More generally, the elementary diagram of every *mutually algebraic* theory admits elimination of quantifiers down to boolean combinations of algebraically existential formulas. (Received September 16, 2013)

1096-03-1727 **Ferit Toska*** (toskaf@ufl.edu). *Compressibility of Countable Subsets of Cantor Space.* Preliminary report.

We introduce a notion of compressibility and n-decidability for countable subsets of Cantor space. We investigate the correspondence between Cantor-Bendixson rank and n-decidability. We show that 1-decidable rank two sets describe each other where the rate of the description is determined by their limit points. (Received September 16, 2013)

1096-03-1729 **Wesley C Calvert*** (wcalvert@siu.edu), Department of Mathematics, Mail Code 4408, 1245 Lincoln Drive, Southern Illinois University, Carbondale, IL 62901, and **Johanna N. Y. Franklin**. *The Power of Uniform Distribution Randomness.*

Weyl showed that for any sequence $(a_n)_{n\in\omega}$ of distinct integers, for almost every real x the sequence $(a_nx)_{n\in\omega}$ is uniformly distributed modulo 1 — that is, the fractional parts of elements of the sequence are uniform in the unit interval. If a real x has this property for every computable sequence $(a_n)_{n\in\omega}$ of distinct integers, then, following Avigad, we say that x is UD-random.

The present talk will describe some problems around UD-randoms, including the fact that no 2-generic can Turing compute a UD-random. (Received September 16, 2013)

1096-03-1764 **Aleksandra Kwiatkowska*** (akwiatk2@math.ucla.edu), 520 Portola Plaza, Math Sciences Building 6363, Los Angeles, CA 90095. *Uniqueness of an invariant probability measure concentrated on an orbit.*

In a recent paper Ackerman, Freer, and Patel characterize countable models for which there exists an invariant (with respect to the logic action) probability measure concentrated on its orbit. In particular, if $\mathcal{M}$ is a Fraïssé limit in a countable relational language, they show that such a measure exists if and only if the age of $\mathcal{M}$ has the strong amalgamation property.

We wish to understand when, if we have an invariant probability measure concentrated on the orbit of a countable model $\mathcal{M}$, we have a unique such measure. We show that when $\mathcal{M}$ is a Fraïssé limit such that its age has the strong amalgamation property and it satisfies an additional condition that holds, for example, when $\mathcal{M}$ has a finite language, such a measure is unique if and only if for each finite n there is exactly one model of cardinality n in the age of $\mathcal{M}$. (Received September 16, 2013)

1096-03-1834 **Miha E. Habič*** (mhabic@gc.cuny.edu), CUNY Graduate Center, Mathematics Department, 365 Fifth Avenue, New York, NY 10016. *Restricting Martin's Axiom to a ccc ground model.*

We consider a variation of Martin's Axiom, called the grounded Martin's Axiom or gMA, which asserts the existence of partially generic filters for ccc posets contained in an inner model of which (a fragment of) the universe is a ccc forcing extension. This principle emerges naturally in the analysis of the classic Solovay-Tennenbaum proof of the consistency of MA. The new axiom is shown to be consistent with the failure of MA and the continuum being any (possibly singular) cardinal of uncountable cofinality. We separate gMA from some of the usually considered weakenings of MA. We show that while gMA implies that the cardinals in the right side of Cichoń's diagram equal the continuum, it is consistent with the left side of the diagram collapsing to ω_1. We also prove that gMA is preserved in a strong way when adding either a Cohen or a random real. (Received September 16, 2013)

1096-03-1847 **Francis Adams*** (fsadams@ufl.edu). *Ultrahomogeneous Computable Structures.*

A structure is ultrahomogeneous if any isomorphism between two finitely generated substructures extends to an automorphism of the whole structure. Countable ultrahomogeneous structures were extensively studied by Fraisse. We investigate the effective categoricity of computable ultrahomogeneous structures, showing that all such structures are Δ^0_2 categorical. We also define a weakening of ultrahomogeneity and look at the effective categoricity of these structures in some specific examples. (Received September 16, 2013)

1096-03-1849 **Jose Iovino*** (iovino@math.utsa.edu). *Metastability of sequences and model theory.*

The concept of metastability of sequences, a variant of the notion of convergence, was introduced by T. Tao in his solution to the problem of norm convergence of multiple ergodic averages for commuting transformations (Ergodic Theory Dynam. Systems 28, 2008). Walsh's ergodic theorem (Ann. of Math. 175, 2012) relies on metastability as well, in order to prove convergence. I will discuss how metastability is related to familiar constructions in classical model theory. This is joint work with Jeremy Avigad. (Received September 16, 2013)

1096-03-1881 **James T. Long*** (jtl209@lehigh.edu), Christmas-Saucon Hall, 14 E Packer Avenue, Bethlehem, PA 18015, and **Lee J. Stanley**. *A Busy Beaver Problem for Infinite-Time Turing Machines.*

In 1962, T. Radó introduced the so-called busy beaver function, which came to occupy an important place in classical (finite-time) computability. Among other things, Radó showed that it asymptotically dominates every classical total computable function from $\mathbb{N}$ to $\mathbb{N}$.

We introduce a generalization to the infinite-time Turing machine (ITTM) setting and show that it asymptotically dominates all ITTM total computable functions from $\mathbb{N}$ to $\mathbb{N}$. We argue that this analogue of one of Radó's main results in the classical setting is strong evidence for the naturality of the generalization. (Received September 16, 2013)

1096-03-1916 **Matthew Jura** (matthew.jura@manhattan.edu), Department of Mathematics, Manhattan College, 4513 Manhattan College Parkway, Riverdale, NY 10471, **Oscar Levin** (oscar.levin@unco.edu), School of Mathematical Sciences, University of Northern Colorado, Campus Box 122, Greeley, CO 80639, and **Tyler Markkanen*** (tyler.markkanen@manhattan.edu), Department of Mathematics, Manhattan College, 4513 Manhattan College Parkway, Riverdale, NY 10471. *Highly computable graphs and their domatic numbers.* Preliminary report.

A dominating set D of a graph G is a set of vertices "near" all other vertices, in that every vertex outside of D is adjacent to a vertex in D. In this talk, we will compare two values associated with G: the domatic number $d(G)$ and *computable* domatic number $d^c(G)$, which give the size of the largest partition and computable partition (respectively) of G into dominating sets. We will produce a highly computable graph G with arbitrarily large domatic number such that $d^c(G) < d(G)$. To build G, we will play the "game" of computable graph theory, as we set up gadgets and spring traps against an adversary who is determined to thwart our moves and force $d^c(G) = d(G)$. Time permitting, we will also consider these two domatic numbers in the context of total dominating sets, where D must now be near *all* vertices, instead of only the ones outside of D. (Received September 16, 2013)

1096-03-1937 **Cameron E. Freer*** (freer@mit.edu). *Random symmetric constructions via inverse limits of finite structures.*

Building on recent results, we provide a method for constructing measures, concentrated on certain classes of countably infinite structures, that are invariant under arbitrary permutations of the underlying set that fix all elements instantiating constant symbols. We use this construction to obtain invariant probability measures concentrated on the class of countable models of certain first-order theories, including measures that do not assign positive probability to the isomorphism class of any single model. We also characterize those transitive Borel G-spaces admitting a G-invariant probability measure, when G is an arbitrary countable product of symmetric groups on a countable set.

Joint work with Nate Ackerman, Jaroslav Nešetřil, and Rehana Patel. (Received September 16, 2013)

1096-03-2014 **Jason M Rute*** (jmr71@math.psu.edu). *Schnorr randomness for noncomputable measures.*

The field of algorithmic randomness allows one to separate the real numbers into those which are random and which are not, with respect to computable statistical tests. Schnorr randomness and Martin-Löf randomness are the two most well-behaved randomness notions. However, unlike Martin-Löf randomness, there has not been much work on Schnorr randomness for non-computable measures. In this talk, I will present a (surprising?) definition of Schnorr randomness for non-computable measures, and I will argue for its robustness. I will also discuss connections with van Lambalgen's theorem, an important theorem about the randomness of pairs. (Received September 17, 2013)

1096-03-2105 **Matthew Jura*** (matthew.jura@manhattan.edu), Department of Mathematics, Manhattan College, 4513 Manhattan College Parkway, Riverdale, NY 10471, **Oscar Levin** (oscar.levin@unco.edu), School of Mathematical Sciences, University of Northern Colorado, Campus Box 122, Greeley, CO 80639, and **Tyler Markkanen** (tyler.markkanen@manhattan.edu), Department of Mathematics, Manhattan College, 4513 Manhattan College Parkway, Riverdale, NY 10471. *Domatic Partitions of A-Computable Graphs and c.e. Permitting.* Preliminary report.

A domatic k-partition of a graph is a partition of the vertex set into k many classes, in which each vertex v is adjacent to some vertex in every partition class of which v is not a member. If A is a set of natural numbers, we say that a locally-finite graph G is A-computable if we can compute the neighborhood relation of G using A as an oracle. Fix a natural number $k > 2$. The authors previously showed that there is a computable, locally finite graph G (so that G is A-computable, where A has the same complexity as the Halting Problem) with a domatic k-partition, but no computable domatic 3-partition. In this talk we will show (using c.e. permitting) that if A is an arbitrary non-computable c.e. set, then there is an A-computable graph G that has a domatic k-partition, but no computable domatic 3-partition. (Received September 17, 2013)

1096-03-2131 **Rebecca M. Steiner*** (rebecca.m.steiner@vanderbilt.edu), Vanderbilt University, Mathematics, 1326 Stevenson Center, Nashville, TN 37203. *Effective Symmetry Breaking.*

Symmetry breaking in combinatorics involves coloring the elements of a structure so that there are no nontrivial automorphisms of the structure which respect the coloring. We say that such a coloring *distinguishes* the structure.

We apply computability theory to this notion and show that there is a computable, finite-valence, pointed graph which is distinguished by a 2-coloring but not by any computable 2-coloring.

We also show that if a computable, finite-branching tree has a distinguishing 2-coloring, then it must have a $\mathbf{0}'$-computable distinguishing 2-coloring. We don't know yet if the same is true in the more general case of computable, finite-valence, pointed graphs. (Received September 17, 2013)

1096-03-2208 **R. Daniel Mauldin*** (mauldin@unt.edu), 2026 Kendolph Dr., Denton, TX 76205. *Dimension of the intersection of a translation of a subset of the reals by a Martin-Lof random real with the set of all numbers with a given constructive dimension .* Preliminary report.

In an article in press for the TAMS, R. Dougherty, J. Lutz , J. Teutsch and myself determined the Hausdorff dimension of the intersection of a translate of the standard middle-third Cantor set by a Marin-Lof random with the set of all numbers with a given constructive Hausdorff dimension. Here I will discuss this sort of analysis for some other subsets of the reals and some of the combinatorial results in additive number theory needed for this analysis. (Received September 17, 2013)

1096-03-2219 **Jennifer Chubb Reimann*** (jcchubb@usfca.edu), USF Department of Mathematics, 2130 Fulton St., San Francisco, CA 94117. *Ordering algebraic structures on trees.*

An ordering of an algebraic structure is an ordering of the elements of that structure that is invariant under the structure's operation. In this talk, we will consider partially and linearly orderable computable groups and semigroups. The families of orderings of such structures form effectively closed sets in Cantor space (or Π^0_1 classes). We will explore this fact and see some ways to exploit it. (Received September 17, 2013)

1096-03-2325 **Joseph S. Miller*** (jmiller@math.wisc.edu), Department of Mathematics, 480 Lincoln Drive, Madison, WI 53706-1388. *High(CR, MLR) and other properties close to PA.*

An oracle X is $\mathrm{High(CR, MLR)}$ if every sequence that is computably random relative to X is Martin-Löf random. It is not hard to show that if X has PA degree, then it computes a martingale dominating the optimal c.e. supermartingale, hence is $\mathrm{High(CR, MLR)}$. This was observed by Franklin, Stephan and Yu, who asked if $\mathrm{High(CR, MLR)}$ is equivalent to PA. They showed that $\mathrm{High(CR, MLR)}$ has measure zero, and that every element computes a Martin-Löf random sequence.

We investigate properties similar to $\mathrm{High(CR, MLR)}$, showing that some are equivalent to PA and separating others from PA, but not settling this question for $\mathrm{High(CR, MLR)}$. We show that if X computes a martingale that dominates the optimal c.e. supermartingale (or even a fairly tame martingale), then it has PA degree. The same proof can be used to show that every C-compression function has PA degree. On the other side, we construct a K-compression function of non-PA degree. We discuss how to improve that construction to build an X of non-PA degree such that every Π^0_1 class of positive measure contains a decidable $\Pi^0_1[X]$ class of positive measure. This property is implied by $\mathrm{High(CR, MLR)}$ but the reverse is open.

This work is joint work with Greenberg and Nies. (Received September 17, 2013)

1096-03-2344 **Cynthia Northrup*** (shepherc@uci.edu). *Applications and Methods of Forcing.*

We will explore forcing, an often misunderstood technique, but an incredibly useful tool for many combinatoric results. My research involves iterated forcing, including versions of Radin forcing, in order to obtain models in which diamond fails or we have reflection. (Received September 17, 2013)

1096-03-2401 **Devon Henkis*** (devonhenkis@my.unt.edu), Department of Mathematics, University of North Texas, Denton, TX 76203, and **Jeff Lobe** and **Steve Jackson**. *Restricted Steinhaus sets in the plane.* Preliminary report.

For each prime p we show the existence of a partial Steinhaus set in the plane for the prime p which can be obtained from the points $\{(\frac{i}{p}, \frac{j}{p}) \colon 0 \leq i, j < p\}$ by translating by integer amounts only in the horizontal direction. We raise several questions concerning these sets. (Received September 17, 2013)

1096-03-2415 **Jef f Lobe***, Department of Mathematics, University of North Texas, Denton, TX 76203, and **Devon Henkis** and **Steve Jackson**. *The finite Steinhaus problem.* Preliminary report.

The finite Steinhaus problem asks whether every finite set $A \subseteq \mathbb{R}^2$ with $|A| = n > 1$ there cannot exist a set $S \subseteq \mathbb{R}^2$ such that $|\pi(A) \cap S| = 1$ for every isometric copy $\pi(A)$ of A. It is easy to see that holds for $n = 2, 3$ and a recent theorem of Xuan (extending results of Miller-Weiss and Gao) shows the result for $n = 4$. We make some connections between this problem and certain algebraic concepts, and show the result for $n = 5, 7$. (Received September 17, 2013)

1096-03-2464 **Oscar Levin*** (oscar.levin@unco.edu), School of Mathematical Sciences, University of Northern Colorado, Campus Box 122, Greeley, CO 80639. *The complexity of transcendence bases in computable ordered fields.*

While every field has a transcendence basis, it might be difficult to *find* that transcendence basis, even if the field is nicely presented. This is an early result in computable field theory of Metakides and Nerode: there are computable fields with no computable transcendence basis. In this talk, we wonder whether it might be easier to locate a transcendence basis in computable *ordered* fields. We will give a negative answer to this question and discuss the potential complexity the transcendence bases. Additionally, we consider the question for purely transcendental fields and their pure transcendence bases. (Received September 17, 2013)

1096-03-2465 **Monroe B Eskew***, 340 Rowland Hall, UC Irvine, Irvine, CA 92617. *Ulam's measure problem, saturated ideals, and cardinal arithmetic.*

Following the discovery that the continuum cannot be a measurable cardinal, Ulam asked, can it be in some sense close to measurable? Is there a "small" collection of countably complete, two-valued measures that collectively measure all subsets of $\mathbb{R}$, and how small? Unknown to Ulam at the time, this question turned out to depend on the consistency of strong set-theoretic principles that far eclipse measurable cardinals.

We explore versions of Ulam's question on different cardinals. On $\aleph_1$, a positive answer has several equivalent formulations, and we explore whether these equivalences generalize to other cardinals. We show that some of them persist under the Generalized Continuum Hypothesis, while others do not. In the course of this, we generalize a consistency result of Woodin using very large cardinals, employ the recently published Duality Theorem of Foreman in essential ways, and draw surprising connections with the Suslin Hypothesis. (Received September 17, 2013)

1096-03-2629 **Joshua A Cole***, jacole1@butler.edu. *A density question where the usual constructions haven't worked.*

A seemingly-hard open problem in computability theory is whether the lattice of Muchnik degrees of effectively closed subsets of Cantor Space is dense. That is, given $A < B$ in this lattice, is there always C such that $A < C < B$? ($X \leq Y$ if from every element of Y, one may effectively obtain an element of X.) Why is such a simple question unresolved, even though it has been settled in the affirmative for very similar structures studied by computability theorists? Priority arguments and forcing constructions are the typical techniques for answering questions in our lattice, but there are significant combinatorial barriers to the use of both methods for the question of density, suggesting the need for something new or improved. Another way to describe the problem is that it is difficult to mix the two types of strategies that seem to be necessary (in either a priority or forcing construction). Some of the author's published results in the study of mass problems, especially results about length of agreement functions in priority arguments, will be used to illustrate this point, as well as examples from the research of others. The current state of the question and partial results will also be covered. (Received September 17, 2013)

05 ► Combinatorics

1096-05-36 **Anant P Godbole*** (godbolea@etsu.edu). *A potpourri of generalized De Bruijn sequences.*

Generalizations of de Bruijn sequences often involve one or more of of the following:

(i) Changing the Rules, e.g., allowing for non-consecutive windows (O-cycles) or introducing larger alphabets when smaller ones do not suffice;

(ii) Changing the Customary Coding, e.g., encoding subsets with their characteristic vectors rather than their elements;

(iii) Introducing non-standard objects for which to exhibit de Bruijn cycles, e.g., words with restrictions, lattice paths, subsets of sizes in a range; words with weights in a range; poset-allocations, etc.

This talk will focus on results that use standard methods to exhibit existence of de Bruijn cycles in each of the above three categories. This is joint work with REU students (several), Master's students (1), and PhD students (1) – who will each be identified at the talk. (Received June 05, 2013)

1096-05-106 **Emily Carter*** (egc3964@rit.edu), School of Mathematical Sciences, Rochester Institute of Technology, Rochester, NY 14623, and **Danielle Gonzalez** (dng2551@rit.edu), Department of Software Engineering, Rochester Institute of Technology, Rochester, 14623. *A graph theoretic analysis of betweenness centrality in transportation and biological networks.*

In transportation and biological networks, certain vertices play a vital role in the connection of subnetworks. This is quantified by betweenness centrality, which is the frequency at which a vertex appears on a shortest path between two other distinct vertices. We precisely compute the betweenness centrality for vertices in several families of graphs including paths, cycles, complete multipartite graphs, and various Cartesian products. Finally, we investigate powers of paths and cycles and present a connection to partitions of integers and integer linear programming. (Received July 30, 2013)

1096-05-107 **Alex Weinstock-Collins*** (weincoll@gmail.com), School of Mathematical Sciences, Rochester Institute of Technology, Rochester, NY 14623, and **Ethan Mark** (topgun@berkeley.edu), Department of Mathematics, Unviersity of California - Berkeley, Berkeley, 94720-3840. *New Bounds on the Bipartite Ramsey Number b(2,5).*

The bipartite Ramsey number $b(n_1, n_2)$ is the smallest positive integer b such that any 2-coloring of the edges of $K_{b,b}$ contains a monochromatic copy of K_{n_1,n_1} in the first color, or K_{n_2,n_2} in the second color. The Zarankiewicz number $z(m, n; s, t)$ is the maximum number of edges in a subgraph of $K_{m,n}$, which does not contain $K_{s,t}$ as a subgraph. The current smallest open case of a bipartite Ramsey number is $16 \leq b(2, 5) \leq 19$, for which the bounds were established by Goddard, Henning, and Oellermann in 2004. In this work we improve these bounds to $17 \leq b(2, 5) \leq 18$, by constructing a suitable 2-coloring of $K_{16,16}$, and proving that all 2-colorings of $K_{18,18}$ contain one of the forbidden subgraphs. The latter proof uses our new bounds on certain Zarankiewicz numbers, in particular $z(10, 14; 5, 5) < 112$, which were obtained by a combination of theoretical arguments and computational techniques. Our current work focuses on improving the bounds on Zarankiewicz numbers and using them to derive better bounds on other bipartite Ramsey numbers. (Received July 30, 2013)

1096-05-109 **David Mehrle*** (dmehrle@andrew.cmu.edu), Department of Mathematical Sciences, Carnegie Mellon University, Pittsburgh, PA 15213, and **Amy Strosser** (amstrosser@email.msmary.edu), School of Natural Science and Mathematics, Mount St. Mary's University, Emmitsburg, MD 21727. *Community detection in graphs based on a generalization of modularity.*

A *community* within a graph is a highly connected subgraph. Finding communities within large graphs is a topic of practical interest in biology, computing, social sciences, and statistical mechanics. Many techniques for community detection in a large graph G are designed to maximize *modularity*, Q, a measure of the quality of a partition of G into two or more communities. Intuitively, modularity measures the difference in edge density found within communities and the edge density expected in a suitably chosen random model. In this talk, we present a natural generalization of modularity based on the difference between the actual and expected number of walks of length ℓ in the graph, which we call $walk - modularity$, Q_ℓ. We develop a community-detection algorithm designed to maximize Q_ℓ using spectral graph theory. Finally, we apply these algorithms to both synthetic and real-world graphs and find that the results favorably compare against cluster-detection algorithms established in literature. (Received July 30, 2013)

1096-05-121 **Richard Hammack*** (rhammack@vcu.edu). *A prime factor theorem for bipartite graphs.*

It has been known for over 40 years that any connected non-bipartite graph factors uniquely into primes over the direct product, and, moreover, that unique factorization can fail for connected bipartite graphs.

But any prime factoring of a connected bipartite graph has exactly one bipartite factor. It has long been suspected that this bipartite factor must be unique (up to isomorphism) among all factorings, but until now this conjecture has withstood proof.

We discuss the context of this result and outline a proof of the conjecture: If a connected bipartite graph G factors in two ways, as $G \cong A \times B$ and $G \cong A' \times B'$, where B and B' are prime and bipartite, then $B \cong B'$. (Received August 01, 2013)

1096-05-134 **Suil O*** (suilo@gsu.edu). *Matchings and eigenvalues in regular graphs or multigraphs.* Preliminary report.

We give lower bounds for the maximum size of a matching in an n-vertex l-edge-connected k-regular graph or multigraph, when $k \geq 3$ and $1 \leq l \leq k - 2$. The bounds are sharp infinitely often, and we characterize when equality holds. This result implies results due to Henning and Yeo and due to West and O.

We also study the relationship between eigenvalues and the existence of certain subgraphs in regular graphs or multigraphs. We obtain a condition on an appropriate eigenvalue that yields a lower bound for the size of a maximum matching of an l-edge-connected k-regular graph or multigraph, when $1 \leq l \leq k-2$. This result implies a result of Cioaba and O. (Received August 07, 2013)

1096-05-137 **David Cook II*** (dcook8@nd.edu), Department of Mathematics, 255 Hurley Building, University of Notre Dame, Notre Dame, IN 46556-4618, and **Uwe Nagel** (uwe.nagel@uky.edu), Department of Mathematics, 715 Patterson Office Tower, University of Kentucky, Lexington, KY 40506-0027. *Lozenge tilings, the weak Lefschetz property, and Laplace equations.*

We describe a connection between signed enumerations of lozenge tilings and the presence of the weak Lefschetz property for monomial ideals in three variables. Using this, we construct projective varieties that satisfy a specific number of Laplace equations of a given order. (Received August 07, 2013)

1096-05-165 **Arni S.R. Srinivasa Rao***, Georgia Regents University, Augusta, GA 30912, and **Damer Blake** and **Fiona Tomley**. *Straight and Non-overlapping Walk on $n \times n$ Grid: Hamiltonian and Rectifiable Paths.*

A configuration for a maximum possible distance through a straight non-overlapping walks (defined in this paper) on a square *grid graphs* is one of the key questions addressed. An area $S \in \mathbb{R}^2$ either with even number of cells $(2n \times 2n)$ or with odd number of cells $((2n+1) \times (2n+1))$ is placed on a *grid graph*, G, which is a subset of an *infinite graph,* G^{∞}. Our main result says, when S has dimension $2n \times 2n$ (n >1) then there always exists at least one configuration for which the walk between $K(i,j)$ and $K(i',j')$ is maximum, i.e. $(2n)^2 - 1$ units, under the hypotheses of straight walk and non overlapping walk and when $S_{ij}(i,j)$ and $S_{i'j'}(i',j')$ have two common vertices between them or $S_{ij}(i,j)$ and $S_{i'j'}(i',j')$ are adjacent cells. If $S_{ij}(i,j)$ and $S_{i'j'}(i',j')$ are non adjacent cells then there doesn't exists a configuration under the same hypotheses for which the walk between $K(i,j)$ and $K(i',j')$ is maximum. We also pose an open problem on multiple walks on finite *grid graphs.* (Received August 12, 2013)

1096-05-213 **Shyam S Kamath*** (shyam.kamath@gmail.com), Department of M.A.C.S., National Institute of Technology Karnataka, Surathkal, Mangalore, 575025, India, and **Prameela Kolake**. *Induced Complementation in Graphs.* Preliminary report.

In this paper, we define a new generalization of the complement of a given graph. Let $G = (V, E)$ be a graph and $S \subseteq V$. The *induced complement of the graph G with respect to the set S*, denoted by G_S, is the graph obtained from the graph G by removing the edges of $\langle S \rangle$ of G and adding the edges which are not in $\langle S \rangle$ of G. Given a set $S \subseteq V$, the graph G is said to be *S-induced self complementary* if $G_S \cong G$. The graph G is said to be *S-induced co-complementary* if $G_S \cong \overline{G}$. This paper presents the study of the different properties of the induced complements of a given graph. (Received August 19, 2013)

1096-05-246 **Ralucca Gera*** (rgera@nps.edu), Department of Applied Mathematics, 1 University Way, Monterey, CA 93943, and **Craig Larson**, **Ryan Pepper** and **Craig Rasmussen**. *Independence in Function Graphs.*

Given two graphs G and H and a function $f \subset V(G) \times V(H)$, Hedetniemi defined the *function graph* GfH by $V(GfH) = V(G) \cup V(H)$ and $E(GfH) = E(G) \cup E(H) \cup \{uv | v = f(u)\}$. Whenever $G \cong H$, the function graph was called a *functigraph* by Chen, Ferrero, Gera and Yi. A function graph is a generalization of the *α-permutation graph* introduced by Chartrand and Harary. The independence number of a graph is the size of a largest set of mutually non-adjacent vertices. In this talk we study the independence number in function graphs. In particular, we give a lower bound in terms of the order and the chromatic number, which improves on some elementary results and has a number of interesting corollaries. (Received August 22, 2013)

1096-05-248 **John Gimbel*** (jggimbel@alaska.edu), P O Box 756660, Fairbanks, AK 997754. *Some questions about generalized colorings.*

A coloring of a graph is simply a partition of the vertex set into parts that satisfy a property. In a traditional coloring, each part is independent. I will talk about several different types of colorings and state a few open questions. (Received August 22, 2013)

1096-05-250 **Laszlo A. Szekely*** (szekely@math.sc.edu). *Zarankiewicz' crossing number conjecture.*

Turán's Brick Factory Problem was raised in a forced labour camp in WWII—in a brick factory. The problem asked about the crossing number of the complete bipartite graph $K_{n,m}$, and the motivation was that n kilns and m storage areas should be connected by rails, minimizing the number of intersections where the bricks tend to fall from the trucks. Zarankiewicz published a solution for the problem and Urbanik confirmed it with an alternative solution. However, Kainen and Ringel discovered an error in the argument that has not been patched since then. I will discuss different concepts of crossing numbers that have been introduced and investigated hoping that they elucidate the problem. It took time to arrive at the clear understanding that we have to deal with different concepts of crossing numbers. This phenomenon fits perfectly Imre Lakatos' Popperian view of mathematics. Lakatos analysed two paradigmatic examples of conceptual development in mathematics: the concept of a real function and Euler's Polyhedral Formula. Note the basic tool for studying crossing numbers is the Polyhedral Formula. (Received August 23, 2013)

1096-05-258 **Daniel W. Cranston*** (dcranston@vcu.edu), Virginia Commonwealth University, Department of Math and Applied Math, 1015 Floyd Avenue, Richmond, VA 23284, and **Landon Rabern**, Branford, CT. *Graphs with $\chi = \Delta$ have Big Cliques.*

Let G be a graph with maximum degree $\Delta \geq 3$. Brooks' Theorem says that if G has chromatic number $\Delta + 1$, then G has a clique on $\Delta + 1$ vertices; otherwise G has chromatic number at most Δ. In 1977 Borodin and Kostochka conjectured that if G is a graph with maximum degree $\Delta \geq 9$ and chromatic number Δ, then G has a clique on Δ vertices. For maximum degree $\Delta \geq 13$, we prove that if G has chromatic number Δ, then G has a clique on at least $\Delta - 3$ vertices. This is joint work with Landon Rabern. (Received August 24, 2013)

1096-05-265 **Xinyun Zhu*** (zhu_x@utpb.edu), 4901 E University, odessa, TX 79762. *A New Recursive relation arising from Fibonacci sequence.* Preliminary report.

The recurrence relation given by

$$-a_n - ba_{n+1} + ca_{n+2} = 1$$

has been studied in "G. Grossman, A. Zeleke and X. Zhu *Recurrence relation with binomial coefficient.* J. Concr. Appl. Math. 8 (2010), no. 4, 602–615", where b and c are real numbers and $c \neq 0$. In this paper, we extend this relation to a more general setting and give a generalization of Theorem 2.1 in [**?**] which in certain conditions gave the following identity

$$-a_{k,n} - ba_{k,n+1} + ca_{k,n+2} = \binom{n+2+k}{n+2}$$

We also study a family of polynomials $a_{0,l,u}$ which is introduced in this paper (Received August 25, 2013)

1096-05-269 **Jonathan L Gross*** (gross@cs.columbia.edu), 458 Computer Science, New York, NY 10027, and **Toufik Mansour**, **Thomas W Tucker** and **David G.L. Wang**. *Log-Concavity of Combinations of Sequences and Applications to Genus Distributions.*

We formulate conditions on a set of log-concave sequences, under which any linear combination of those sequences is log-concave, and further, of conditions under which linear combinations of log-concave sequences that have been transformed by convolution are log-concave. These conditions involve relations on sequences called *synchronicity* and *ratio-dominance*, and a characterization of some bivariate sequences as *lexicographic*. We are motivated by the 25-year old conjecture that the genus distribution of every graph is log-concave. Although calculating genus distributions is NP-hard, they have been calculated explicitly for many graphs of tractable size, and the three conditions have been observed to occur in the *partitioned genus distributions* of all such graphs. They are used here to prove the log-concavity of the genus distributions of graphs constructed by iterative amalgamation of double-rooted graph fragments whose genus distributions adhere to these conditions, even though it is known that the genus polynomials of some such graphs have imaginary roots. A blend of topological and combinatorial arguments demonstrates that log-concavity is preserved through the iterations. (Received August 25, 2013)

1096-05-280 **Kassie Archer*** (kassie.r.archer.gr@dartmouth.edu) and **Sergi Elizalde**. *Cyclic permutations realized by the signed shift.*

Suppose W_k is the set of infinite words on k-letters and Σ_k is the k-shift on W_k defined by

$$\Sigma_k(a_1a_2a_3\ldots) = a_2a_3a_4\ldots.$$

By equipping W_k with the lexicographic ordering, we can define the *patterns* associated to Σ_k to be permutations in the same relative order as orbits of words with respect to Σ_k. Restricting to the set of periodic words, the patters we get are called *periodic patterns*. We find a bijection between the periodic patterns and cyclic permutations with exactly $k-1$ descents and we enumerate these permutations, recovering results of Gessel and Reutenauer.

We generalize this result by looking at signed shifts, a family of maps on W_k. The k-shift is a special case of a signed shift. We find that the periodic patterns associated with a given signed shift are in bijection with the cyclic permutations in a given permutation class which can be described in terms of pattern avoidance.

Using this bijection, we find interesting combinatorial results, including the enumeration of the set of cyclic permutations in certain permutation classes and a bijection between unimodal cyclic permutations and primitive binary necklaces with an odd number of ones. (Received August 26, 2013)

1096-05-300 **Henry Martyn Mulder*** (hmmulder@few.eur.nl). *The Meta-Conjecture for median graphs.*

At first sight trees and hypercubes do not have much in common, except that K_1 and K_2 are both a tree as well as a hypercube. A closer look at these classes gives an interesting observation. There is a construction that works for both classes, which produces any tree from a smaller tree or any hypercube from a smaller hypercube (except for the smallest case K_1). This leads us to the class of all graphs produced by this construction from K_1: the median graphs. This also suggests the following Meta-Conjecture (formulated first by HMM in 1990): "Any property shared by the trees and the hypercubes that makes sense is shared by all median graphs". We present the details of this Meta-Conjecture, examples of the many theorems that have resulted from it, and some possibilities for future results. We also present generalizations and related results. (Received August 27, 2013)

1096-05-308 **Anthony Bonato***, Department of Mathematics, Toronto, Ontario , Canada. *Conjectures on Cops and Robbers.*

The game of Cops and Robbers played on graphs gives rise to a rich set of conjectures, mainly associated with the cop number of a graph. Arguably the most important such conjecture is Meyniel's, which posits an $O(\sqrt{n})$ upper bound on the cop number of a connected graph of order n. We discuss the state-of-the-art on Meyniel's conjecture, and explore other conjectures on cop number ranging from topics within computational, probabilistic, and topological graph theory. (Received August 27, 2013)

1096-05-318 **Edward R. Scheinerman*** (ers@jhu.edu), Applied Mathematics & Statistic Department, Johns Hopkins University, Baltimore, MD 21218, and **Yiguang Zhang**, Applied Mathematics & Statistics Department, Johns Hopkins University, Baltimore, MD 21218. *Random Threshold Directed Graphs.* Preliminary report.

A directed graph D is called a *threshold digraph* provided there exists a pair of weighting functions $f, g : V(G) \to \mathbf{R}$ such that for distinct $u, v \in V(D)$ we have the arc $u \to v$ exactly when $f(u) + g(v) \geq 1$. We generate a threshold digraph at random by choosing the weights $\{f(u), g(u) : u \in V\}$ independently and uniformly at random from $[0, 1]$.

We show that this model of random threshold digraphs is equivalent to another, purely combinatorial random model based on linear extensions of an associated poset. We then exploit his equivalence to derive exact and asymptotic properties of random threshold digraphs. For example, we show that the probability that a random threshold digraph on n vertices is strongly connected converges to $\frac{1}{4}$ as $n \to \infty$. (Received August 28, 2013)

1096-05-320 **Jie Ma*** (majiemath@gmail.com) and **Humberto Naves**. *Maximizing the number of proper colorings of graphs.* Preliminary report.

We study an old problem of Linial and Wilf to find the graphs with n vertices and m edges which maximize the number of proper q-colorings of their vertices. In a breakthrough paper, Loh, Pikhurko and Sudakov reduced the problem to an optimization problem and solved asymptotically for many ranges of parameters. We prove the following structural result which tells us how the solution of the optimization looks like: for any instance, the optimization problem always has a solution which corresponds to either a complete multipartite graph or a graph obtained from complete multipartite graph by removing edges of two bipartite subgraphs.

We then apply this structural result of optimal graphs to general instances, including a conjecture of Lazebnik from 1989 which asserts that for any $q \geq s \geq 2$, the Turán graph $T_s(n)$ has the maximum number of q-colorings among all graphs with the same number of vertices and edges. We disprove this conjecture by providing infinity many counterexamples (s, q) for $s + 7 < q < 2s - 3$. On the positive side, we show that when $q \geq \Omega(s^2)$ the Turan graph $T_s(n)$ indeed achieves the maximum number of q-colorings.

Joint work with Humberto Naves. (Received August 28, 2013)

1096-05-325 **Florian Pfender*** (florian.pfender@ucdenver.edu), **Maciej Kalkowski** and **Michał Karoński**. *The 1-2-3 Conjecture for Hypergraphs.*

The 1-2-3 Conjecture from 2004 by Karoński, Łuczak and Thomason states that you can weigh the edges of any connected graph on at least 3 vertices with weights from the set $\{1, 2, 3\}$ such that the weighted vertex degrees induce a proper vertex coloring.

This conjecture has spurred a lot of activity in recent years, but it looks like we are still ways away from solving it completely. In this talk I will present some new results on the equivalent question for hypergraphs. Surprisingly, we can give sharp bounds for large classes of hypergraphs. (Received August 28, 2013)

1096-05-344 **Kathleen Lan** and **Amanda Laubmeier***, allusive@email.arizona.edu, and **Ruyue (Julia) Yuan**. *Covering n Permutations with $n + k$ Permutations.* Preliminary report.

Consider a permutation π of length n; we say that a permutation π' of length $n + 1$ covers this permutation if π is contained as a subpattern of π'. Existing research gives us bounds on the order m of a minimal set of permutations of size $n + 1$ necessary to cover all permutations of size n . We extend this research to the general case where π' is of length $n + k$ for a natural number k and present bounds on the order of a minimal set of permutations necessary to cover $\lambda \geq 1$ times every permutation of size n. We also present preliminary results on the problem of embedding permutations of length n in permutations of length $n + 1$. (Received August 29, 2013)

1096-05-376 **Lynn Chua*** (chualynn@mit.edu) and **Krishanu Roy Sankar**. *Equipopularity classes of 132-avoiding permutations.*

The popularity of a pattern p in a set of permutations is the sum of the number of copies of p in each permutation of the set. We study pattern popularity in the set of 132-avoiding permutations. Two patterns are equipopular if, for all n, they have the same popularity in the set of length-n 132-avoiding permutations. There is a well-known bijection between 132-avoiding permutations and binary plane trees. The spines of a binary plane tree are defined as the connected components when all edges connecting left children to their parents are deleted, and the spine structure is the sorted sequence of lengths of the spines. Rudolph shows that patterns of the same length are equipopular if their associated binary plane trees have the same spine structure. We prove the converse of this result using the method of generating functions, which gives a complete classification of 132-avoiding permutations into equipopularity classes. (Received August 30, 2013)

1096-05-378 **Xi Sisi Shen*** (xss2000@columbia.edu), New York, NY 10027, and **Aaron S Williams**. *A 'Hot Potato' Gray code for Permutations.* Preliminary report.

We prove the existence of a 'Hot Potato' Gray code for permutations that always transposes the value n with a value that is one or two positions to its left or right, circularly. This appears to be the first permutation Gray code that restricts both the value and position of the transposed symbols. Our construction relies on the doubly-adjacent Gray code by Compton and Williamson. This is joint work with Aaron Williams. (Received August 31, 2013)

1096-05-385 **Ruyue (Julia) Yuan*** (ruyue.yuan@valpo.edu), 1509 Chapel Dr., Unit 2443, Valparaiso University, Valparaiso, IN 46383, and **Zoe Koch** (kochzoe@gmail.com), 0942 Heritage Center, Salt Lake City, UT 84112. *Intractable Sums Tamed: New Upper Bounds for Covering Arrays.* Preliminary report.

In a t-covering array with k rows and n columns, with each element inserted randomly from an alphabet of size q, we select any t columns and look for the minimum number of rows k that can lead to the appearance of all q^t possible words among the rows of the selected t columns. We use a probabilistic method, namely the ErdH os-Lovasz local lemma, in conjunction with a method to estimate complex binomial sums, to address this question and find generalized formulas for calculating upper bounds on k in arrays of different sizes. (Received September 08, 2013)

1096-05-386 **Douglas B. West*** (west@math.uiuc.edu). *Selected extremal problems in graph theory.*

The speaker will describe a variety of unsolved extremal problems in graph theory. Topics will include graph representations, domination, edge-decomposition, coloring, choosability, etc. (Received September 01, 2013)

1096-05-422 **Craig E Larson***, clarson@vcu.edu. *Eigenvalues of Saturated Hydrocarbons.*

We propose a simplified Hückel-type molecular-orbital (MO) model for the valence electrons of saturated hydrocarbons and consider the consequent eigenvalue spectrum. We obtain a first foundational result, which every chemist "knows", namely that: alkanes are stable, with half their (Hückel-type MO) eigenvalues positive and half negative. (Received September 03, 2013)

1096-05-432 **Adam King*** (adking08@louisville.edu) and **Zach Gabor**. *Minimal Covering Sets on Young's Lattice.*

We define a covering relation on the lattice of integer partitions such that a partition of size n, λ_n covers a partition of size $n - 1$, λ_{n-1} if term-by-term subtraction $\lambda_n - \lambda_{n-1}$ yields no negative terms. We examine sets of partitions of n which collectively cover every partition of size $n-1$, and find bounds on the size of such a covering set. We discuss conjectures regarding the distribution of part sizes within a random partition, and the potential improvement to our minimal covering set results. (Received September 03, 2013)

1096-05-446 **Lowell Abrams*** (labrams@gwu.edu). *Fixed-point rotation families of cellular automorphisms.*

A fixed-point rotation family is a one-parameter family of cellular automorphisms of cellularly embedded graphs which satisfy the following conditions: Each automorphism is pseudofree but not free; the respective orders of the automorphisms are given by a linear function of genus; all quotient surfaces are the same; all genus greater than 1 are represented. In recent work, Abrams and Slilaty defined a notion of reducibility for cellular automorphisms of embedded graphs; we use this framework to classify all irreducible fixed-point rotation families. (Received September 03, 2013)

1096-05-447 **Stephanie DeGraaf*** (sdegraaf@iastate.edu), **Kai Orans** and **Ruyue (Julia) Yuan**. *Avoiding Permutation Patterns in Ordered Set Partitions.* Preliminary report.

We consider the enumeration of ordered set partitions avoiding a permutation pattern. Recently, many results have been published concerning this topic, including enumerative results by Bruner, Chen et al., Godbole et al., and Kasraoui. We specifically consider Kasraoui's summation formula for the number of ordered set partitions that avoid a pattern of length 3, and analyze it in a variety of ways. Through parameterization, we find the value of i for which the maximum value in the sum occurs. We develop a simplified approximation of the formula, and we then obtain a lower bound for the resulting sum. All results are thus asymptotic but the number of parts in the partition is allowed to grow to infinity with n. (Received September 03, 2013)

1096-05-448 **Daniel Orr** and **Mark Shimozono*** (mshimo@math.vt.edu). *Specializations of nonsymmetric Macdonald-Koornwinder polynomials.*

We generalize the Ram-Yip formula for the nonsymmetric Macdonald polynomials $E_\lambda(X;q;t_\bullet)$ to nonreduced affine root systems. We obtain combinatorial formulas for $E_\lambda(X;q;0)$ for all affine root systems. For an untwisted affine algebra, Lenart, Naito, Sagaki, Schilling and the second author had obtained this result as well as connections with Kirillov-Reshetikhin characters and level-zero Lakshmibai-Seshadri paths. To obtain this formula for $A_{2n}^{(2)}$ and its affine dual, we use the nonreduced Ram-Yip formula for nonsymmetric Koornwinder polynomials. These $t=0$ formulas require a generalization of the notion of quantum Bruhat graph (which came from quantum cohomology of flag manifolds) from untwisted affine root systems to any affine root system. Cherednik and the first author studied $E_\lambda(X;q;\infty)$ in relation to the difference Toda system and conjectured that it describes the PBW filtration of an affine Demazure module. We obtain a combinatorial formula for this case and use it to verify their conjecture about the coefficients of extremal weights. We also obtain a formula for $E_\lambda(X;\infty;t)$, which are the Whittaker functions studied by Brubaker, Bump, and Licata. (Received September 03, 2013)

1096-05-452 **Catherine Erbes**, **Theodore Molla**, **Sarah Mousley** and **Michael Santana*** (santana@illinois.edu), Department of Mathematics, 1409 W Green Street, Urbana, IL 61801. *A Conjecture on Spanning Trees with Fixed Leaf Distance.* Preliminary report.

Let $i(G)$ denote the number of isolated vertices in a graph G. In 2001, Kaneko conjectured the following: let $d \geq 3$, and let G be a connected, n-vertex graph with $n \geq d+1$. If $i(G-S) < \frac{2}{d-2}|S|, \forall S \subseteq V(G)$, then G has a spanning tree T with leaf distance $\geq d$; that is, the distance in T between any pair of leaves is $\geq d$. This conjecture has been verified for only $3 \leq d \leq 4$. We will present Kaneko's sharpness example, and then translate the inequality provided in the conjecture to the language of neighborhood unions. In this language, we will present a more refined sharpness example and prove the conjecture for $d \geq n/3$. This result will be a corollary from a weaker hypothesis, leading the authors to present a new conjecture on the existence of spanning trees with leaf distance $\geq d$. Several open problems will be presented at the end of the talk. (Received September 03, 2013)

1096-05-465 **Karola Meszaros***, 212 Garden Ave, Ithaca, NY 14853. *Product formulas for the volumes of flow polytopes.*

I will present product formulas for the volumes of a special class of flow polytopes. This class is inspired by the Chan-Robins-Yuen polytope, whose volume is equal to a product of Catalan numbers (although there is no known combinatorial proof of this fact!). I will explain how certain algebras defined by Kirillov encode subdivisions of flow polytopes. Finally, I will show how to derive identities involving the Kostant partition function, using a connection with flow polytopes discovered by Postnikov and Stanley. (Received September 04, 2013)

1096-05-476 **M. Krul***, 5 Lippitt Ave., Kingston, RI 02881, and **L. Thoma**. *Algebraic Characterization of Hypergraph Colorings.*

A hypergraph is properly 2-colorable if each vertex can be colored by one of two colors such that no edge is monochromatic. In 1997 Hillar gave a complete characterization of the k-colorability of graphs using algebraic methods. We generalize Hillar's work and give a complete algebraic characterization of the 2-colorability of r-uniform hypergraphs. Further, we prove a decomposition result for hypergraph 2-colorings and use it to determine if a hypergraph is conflict-free colorable or not. We will also discuss extensions of our results to k-colorability of uniform hypergraphs. (Received September 04, 2013)

1096-05-481 **Chris Godsil***, cgodsil@uwaterloo.ca. *Are almost all graphs determined by their spectrum?* Preliminary report.

The spectrum of the adjacency matrix of a graph is a useful and interesting invariant. In a perfect world, some simple variant of the spectrum would characterize the graph, but here below there are counterexamples to any reasonable idea. Nonetheless Willem Haemers has conjectured that almost all graphs are determined by their spectrum. In my talk I will explain why I think he is likely right. (Received September 04, 2013)

1096-05-487 **Kyle D Calderhead*** (kcalderhead@malone.edu), Kyle Calderhead, Malone University/Math. & Comp. Sci., 2600 Cleveland Ave NW, Canton, OH 44709. *Hilbert-like Curves on Hexagonal Grids and a Realization using Crochet.*

The standard Hilbert curve (a space-filling fractal) can be easily generalized to use any rook's tour (i.e. Hamiltonian path through a square grid) as the base motif, provided the endpoints are adjacent corners. The number of such paths is well-known for small boards — it was the subject of a recent *CMJ* article, and the sequence itself (which is OEIS entry A000532) can be traced back to Möbius in the mid-1800's.

Trying to build a similar construction starting with paths through hexagonal tiles leads to difficulties that do not arise in the square case, namely, that some paths cannot be fit together to form the next iteration of the curve. In fact, there are some curves which will form the first iteration, but then are unable to fit together to form a later iterate.

This talk will explore some of these difficulties, along with some of the successes in finding such curves, and conclude with a realization of one of these curves in the form of a crocheted blanket. (Received September 04, 2013)

1096-05-503 **Victoria E. Horan*** (victoria.horan.1@us.af.mil), 525 Brooks Road, Rome, NY 13323. *Overlap Cycles.* Preliminary report.

Universal cycles and Gray codes are examples of listing elements of a combinatorial family in a specific manner, and overlap cycles were invented as a generalization of these in 2010. An s-overlap cycle orders a set of strings so that the last s letters of one string are the first s letters of the next (in order). Many combinatorial objects, such as permutations, do not lend themselves immediately to the universal cycle structure. In this talk we will discuss recent results over various types of objects such as permutations. (Received September 05, 2013)

1096-05-505 **Caitlin Phifer*** (caitlin@math.uri.edu). *The Cycle Intersection Matrix and Applications to Planar Graphs.*

Given a finite connected planar graph G with s finite faces, we define the *cycle-intersection matrix*, $C(G) = (c_{ij})$ to be a symmetric matrix of order $s \times s$ where c_{ii} is the length of the cycle which bounds finite face i, and c_{ij} the negative of the number of common edges in the cycles bounding faces i and j for $i \neq j$. We will show that $\det C(G)$ equals the number of spanning trees in G. We show an interesting connection between the determinant of $C(G)$ to the Fibonacci sequence when G is a certain triangulation of an n-gon by non-overlapping diagonals. (Received September 05, 2013)

1096-05-525 **Eric Andrews** and **Ping Zhang*** (ping.zhang@wmich.edu), Department of Mathematics, Western Michigan University, Kalamazoo, MI 49009. *A Graph Theoretic Division Algorithm.*

A graph H is said to divide a graph G if G has an H-decomposition. A decomposition $\{H_1, H_2, \ldots, H_k, R\}$ of G is called an H-maximal k-decomposition if $H_i \cong H$ for $1 \le i \le k$ and R contains no subgraph isomorphic to H. Let $Min(G,H)$ and $Max(G,H)$ be the minimum and maximum k, respectively, for which G has an H-maximal k-decomposition. A graph H without isolated vertices is said to possess the intermediate decomposition property if for each connected graph G and each integer k with $Min(G,H) \le k \le Max(G,H)$, there exists an H-maximal k-decomposition of G. Results and questions are presented in this area of research. (Received September 05, 2013)

1096-05-526 **Gary Chartrand**, **Heather Jordon** and **Ping Zhang*** (ping.zhang@wmich.edu), Department of Mathematics, Western Michigan University, Kalamazoo, MI 49008. *On the Eulerian Cycle Decomposition Conjecture.*

A classic theorem of Veblen states that a connected graph G has a cycle decomposition if and only if G is Eulerian. The number of odd cycles in a cycle decomposition of an Eulerian graph G and the size of G are therefore of the same parity. A conjecture on this topic is presented as are some related results and problems. (Received September 05, 2013)

1096-05-562 **Eric S. Andrews*** (eric.s.andrews@wmich.edu), Departement of Mathematics, Western Michigan University, Kalamazoo, MI 49008. *On Irregular Eulerian Walks in Graphs.*

A closed walk in a connected graph G that contains every edge of G exactly once is an Eulerian circuit. A graph is Eulerian if it contains an Eulerian circuit. It is well known that a connected graph G is Eulerian if and only if every vertex of G is even. An Eulerian walk in a connected graph G is a closed walk that contains every edge of G at least once, while an irregular Eulerian walk in G is an Eulerian walk that encounters no two edges of G the same number of times. We present some results and open questions in this area of research. (Received September 06, 2013)

1096-05-578 **Alex Fink*** (a.fink@qmul.ac.uk) and **Felipe Rincón**. *Stiefel tropical linear spaces.*

The Stiefel map is the obvious rational map from a space of matrices to the Grassmannian given by taking the span of the rows. Unlike the classical situation, it is not surjective tropically. The linear spaces in its image are the *Stiefel tropical linear spaces*, and are in various senses the only linear spaces one can easily get at by imitating classical techniques.

We discuss the combinatorics of Stiefel tropical linear spaces as polyhedral complexes, and a useful collection of local coordinate systems which together cover the image of the Stiefel map, allowing investigations into its global structure. (Received September 06, 2013)

1096-05-583 **Jonathan L. Gross*** (gross@cs.columbia.edu), 458 Computer Science, New York, NY 10027. *All Graph Genus Distributions Are Log-Concave, and Related Conjectures.*

In the *genus polynomial* $\Gamma_G(z)$ for a graph G, the coefficient of z^k is the number of different cellular embeddings of G in the surface S_k of genus k. It was conjectured in 1989 that all genus distributions are log-concave, which we have taken to calling the *LCGD Conjecture*. By a theorem of Newton, a real-rooted polynomial with non-negative coefficients is necessarily log-concave. Log-concavity of a sequence implies unimodality. There is a growing list of graph families whose genus polynomials have been proved to be log-concave, including some that have been proved to be real-rooted. There are examples of graphs whose genus polynomials are log-concave, but not real-rooted. In addition to the progress on the LCGD Conjecture itself, we also discuss the growing list of related conjectures and spinoff problems to be solved. (Received September 06, 2013)

1096-05-590 **Fred S Roberts*** (froberts@dimacs.rutgers.edu). *Competition Graphs and Food Webs: Some of My Favorite Conjectures.*

Ecology is sometimes the source of interesting graph-theoretical problems. Starting from properties of ecosystems, in particular normal, healthy competition between species, Joel Cohen introduced the idea of a competition graph corresponding to a food web. There have been hundreds of papers on this topic since then, and applications ranging from coding to scheduling. Recently, one long-standing conjecture about competition graphs, the Opsut Conjecture, was settled. However, several other important conjectures remain and this talk will explore them. (Received September 07, 2013)

1096-05-593 **Benjamin J. Wyser** (bwyser@uiuc.edu), UIUC Math Dept 1409 W. Green Street, Urbana, IL 61801, and **Alexander Yong*** (ayong@uiuc.edu), UIUC Math Dept., 1409 W. Green Street, Urbana, IL 61801. *Polynomials for $GL_p \times GL_q$ orbit closures in the flag variety.*

The subgroup $K = GL_p \times GL_q$ of GL_{p+q} acts on the flag variety GL_{p+q}/B with finitely many orbits. We introduce a family of polynomials that specializes to representatives for cohomology classes of the orbit closures in the Borel model. We define and study K-orbit determinantal ideals to support the geometric naturality of these representatives. Using a modification of these ideals, we describe an analogy between two local singularity measures: the H-polynomials and the Kazhdan-Lusztig-Vogan polynomials. (Received September 07, 2013)

1096-05-601 **Abbas M Alhakim*** (aa145@aub.edu.lb). *Generating and Compressing De Bruijn Sequences Using Preference Diagrams.*

This talk is about the generation of classical de Bruijn sequences using the method of preference functions, the prefer-one sequence, aka the Ford sequence, being the basic example of this method. This method was originally discussed in 1960s but apparently it was soon thought of as inefficient because of space efficiency considerations. A recent paper by the author shows that most de Bruijn sequences can be "compressed" into a table that is much smaller than its original size. Also a preference table of an order n de Bruijn sequence can itself be used to generate de Bruijn sequences of all orders larger than n (a la Ford algorithm). We also discuss how such tables (or functions) can be constructed to generate de Bruijn sequences with a few forbidden patterns. (Received September 07, 2013)

1096-05-625 **Tri Lai*** (tmlai@indiana.edu), 2001 E Lingelbach Ln, Apt 238, Bloomington, IN 47408. *New aspects of lattice regions whose tilings are enumerated by perfect powers.*

In 2003, Ciucu presented a unified way to enumerate tilings of lattice regions by using a certain Reduction Theorem (Ciucu, Perfect Matchings and Perfect Powers, Journal of Algebraic Combinatorics, 2003). We continue this line of work by investigating new families of lattice regions whose tilings are enumerated by perfect powers or products of several perfect powers. We prove a multi-parameter generalization of Bo-Yin Yang's theorem on fortresses (B.-Y. Yang, Ph.D. thesis, Department of Mathematics, MIT, MA, 1991). On the square lattice $\mathbb{Z}^2$ with zigzag paths drawn in, we consider two particular families of regions whose numbers of tilings are always a power of 3 or twice a power of 3. The latter result provides a new proof for a conjecture of Matt Blum first proved by Ciucu. We also obtain a large number of new lattices by periodically applying two simple subgraph replacement rules to the square lattice $\mathbb{Z}^2$. On some of those lattices, we get new families of regions whose numbers of tilings are given by products of several perfect powers. In addition, we prove a simple product formula for the number of tilings of a certain family of regions on a variant of the triangular lattice. (Received September 08, 2013)

1096-05-653 **Zoe Koch*** (kochzoe@gmail.com), 0942 Heritage Center, Salt Lake City, UT 84112. *Increasing Representations in Additive Bases.* Preliminary report.

A set $A \subseteq [n] \cup \{0\}$ is said to be a 2-additive basis for $[n]$ if each $j \in [n]$ can be written as $j = x + y$, $x, y \subseteq A$, $x \leq y$. If we pick each integer in $[n] \cup \{0\}$ independently with probability $p = p_n \to 0$, thus getting a random set A, we can analyze the probability of obtaining a 2-additive basis. We can also manipulate $r_k(n)$, the number of ways of representing each integer n as the sum of k elements from A. We focus $r_k(n)$ values to $2 \leq r_k(n) \leq Clogn$ and truncate our area of interest to a target sum-set $[\alpha n, (2-\alpha)n]$ for some $0 < \alpha < 1$. We then use probability methods to look for a threshold for the emergence of a 2-additive basis with multiple representations of a specified amount. (Received September 08, 2013)

1096-05-669 **Jonathan L. Gross** and **Toufik Mansour*** (tmansour@univ.haifa.ac.il), Department of Mathematics, University of Haifa, 3498838 Haifa, Israel, and **Thomas W. Tucker**. *Log-Concavity of Genus Distributions of Ring-Like Families of Graphs.*

We calculate genus distribution formulas for several ring-like families of graphs, and we prove that they are log-concave. Although log-concavity has been proved for many linear families of graphs, the only other ring-like family (of rising maximum genus) known to have log-concave genus distributions is the Ringel ladders. These new log-concavity results are further experimental evidence in support of the long-standing conjecture that the genus distribution of every graph is log-concave. We prove also that each coordinate of the partitioned genus distributions of various iterative bar-amalgamations of copies of a given graph G is log-concave, which is an unprecedented result for partitioned genus distributions. Our results are achieved via introduction of the concept of a vectorized production matrix, which is likely to prove a highly useful operator in the theory of genus distributions. (Received September 09, 2013)

1096-05-670 **Jonathan L. Gross**, **Toufik Mansour**, **Thomas W. Tucker** and **David G.L. Wang*** (david.combin@gmail.com), Department of Mathematics, University of Haifa, 3498838 Haifa, Israel. *Log-concavity of the genus polynomials of Ringel ladders.*

A Ringel ladder can be formed by a self-bar-amalgamation operation on a symmetric ladder, that is, by joining the root vertices on its end-rungs. The present authors have previously derived criteria under which linear chains of copies of one or more graphs have log-concave genus polynomials. Herein we establish Ringel ladders as the first significant non-linear infinite family of graphs known to have log-concave genus polynomials. We construct an algebraic representation of self-bar-amalgamation as a matrix operation, to be applied to a vector representation of the partitioned genus distribution of a symmetric ladder. Analysis of the resulting genus polynomial involves the use of Chebyshev polynomials. This paper continues our quest to affirm the quarter-century-old conjecture that all graphs have log-concave genus polynomials. (Received September 09, 2013)

1096-05-687 **Yichao Chen*** (ycchen@hnu.edu.cn), Changsha, Hunan 410082, Peoples Rep of China, **Jonathan L. Gross** (gross@cs.columbia.edu), New York, NY 10027, and **Xiaodong HU** (xdhu@amss.ac.cn), Beijing, Beijing 100190, Peoples Rep of China. *Enumeration of Digraph Embeddings.*

A 2-cell embedding of an Eulerian digraph D into a closed surface is said to be *directed* if the boundary of each face is a directed closed walk in D. The *directed genus distribution* of the digraph D is known for very few classes of graphs, compared to the genus distribution of a graph. In this talk, we will introduces a variety of methods for calculating the directed genus distributions of Eulerian digraphs. We use them to derive an explicit formula for the directed genus distribution of any 4-regular outerplanar digraph. We show that the directed genus distribution of such a digraph is determined by the *red-blue star decompositions* of the *characteristic tree* for an outerplanar embedding. The directed genus distribution of a 4-regular outerplanar digraph is proved to be *log-concave*. We introduce *Eulerian splitting* at a vertex of a digraph, and we prove a splitting theorem for digraph embedding distributions that is analogous to the splitting theorem for (undirected) graph embedding distributions. This new splitting theorem allows conversion of the enumeration of embeddings of a digraph with vertex degrees larger than 4 into a problem of enumerating the embeddings of some 4-regular digraphs. (Received September 16, 2013)

1096-05-704 **Hao Huang*** (huanghao@math.ias.edu), S-004 Simonyi Hall, Institute for Advanced Study, Princeton, NJ 08540. *The inducibility of directed graphs.*

In modern extremal combinatorics, a substantial number of problems study the asymptotic relations between densities of subgraphs. One particularly interesting topic called inducibility is to find the maximum possible induced density of a given subgraph. We study this problem in the digraph setting, and solve the inducibilities for all the complete bipartite digraphs. Our result confirms a conjecture by Falgas-Ravry and Vaughan, and provides the first known explicit instance of density problem for which one can prove extremality of an iterated blow-up construction. (Received September 09, 2013)

1096-05-706 **Alexander Halperin*** (adh208@lehigh.edu), Department of Mathematics, Lehigh University, 14 East Packer Avenue, Bethlehem, PA 18015. *On semi-linkage with prescribed lengths.* Preliminary report.

Let H be a multigraph, and consider a set $S \subseteq V(H)$. A (simple) graph G is (H,S)-*semi-linked* if every injective function $f : S \to V(G)$ can be extended into an H-subdivision (called an (H,S)-*semi-linkage*) in G. Let w be a weight function of positive integers $w_e \geq 14$ corresponding to distinct edges $e \in E(H)$. A graph G is (H,S,w)-*semi-linked* if every injective function $f : S \to V(G)$ can be extended into an (H,S)-semi-linkage in G such that each path corresponding to each edge $e \in E(H)$ has length w_e. We establish a sharp minimum degree condition for a sufficiently large graph G to be (H,S,w)-semi-linked. (Received September 09, 2013)

1096-05-718 **Scott M Corry*** (corrys@lawrence.edu), Lawrence University, Department of Mathematics, 711 E. Boldt Way – SPC 24, Appleton, WI 54911. *Harmonic Group Actions, Genus Bounds, and Combinatorial Maps.* Preliminary report.

Suppose that G is a group of automorphisms of a finite graph X. The G-action on X is called *harmonic* if for every subgroup $H < G$, the quotient morphism $\Gamma \to \Gamma/H$ is harmonic in the sense of Baker-Norine. This is a strong condition, and we will present sharp linear genus bounds on the maximal size of harmonic group actions on finite graphs – these are graph-analogues of the Hurwitz (upper) and Accola-Maclachlan (lower) bounds for Riemann surfaces. Furthermore, we will describe a connection between the harmonic group actions that achieve these bounds and the classical topic of combinatorial maps. (Received September 09, 2013)

1096-05-752 **Kirsti Wash*** (kirstiw@clemson.edu). *Prime factorization in the generalized hierarchical product.*

In 2008, Barrière et al. introduced the generalized hierarchical product of graphs. This is a generalization of the Cartesian product of graphs in that we can represent a particular Cartesian product as a generalized hierarchical product. It is known that every connected graph has a unique prime factor decomposition with respect to the Cartesian product. In this talk, we generalize this result to show that connected graphs, indeed, have a unique prime factor decomposition with respect to the generalized hierarchical product. This is joint work with Sarah Anderson of Clemson University. (Received September 09, 2013)

1096-05-755 **Stephanie De Graaf**, **Zoe Koch** and **Kathleen Lan*** (kathleen.lan@duke.edu).
Shattering sub-permutations in an array of n-permutations. Preliminary report.

We consider an n-column array of permutations on $[n]$ and study $k_{t,\lambda}$, the smallest number of rows needed to observe all order-isomorphic t-permutations λ times in any choice of t columns. Using the Lovasz Local Lemma, we improve the known upper bound for $k_{t,1}$ when $t \geq 4$:

$$k_{t,1} \leq \frac{(t-1)\log_2(n)}{\log_2(\frac{t!}{t!-1})}(1+o(1)).$$

We also use the Lovasz Local Lemma to obtain an upper bound for $k_{t,\lambda}$ when $t \geq 4$ and $\lambda \geq 2$, which is

$$k_{t,\lambda} < \frac{(t-1)\log_2(n) + (\lambda-1)\log_2\log_2(n)}{\log_2(\frac{t!}{t!-1})}(1+o(1)).$$

We are also adapting methods in Godbole, Pinella, Zhuang (2013) to determine the threshold number of rows needed to observe all $t!$ order-isomorphic t-permutations in every set of t columns with low or high probability. Thus far, we have determined that this threshold occurs on the order of $\frac{t\log_2(n)}{\log_2(f(t))}$ (for some positive function $f(t)$) rather than on the order of $\frac{(t-1)\log_2(n)}{\log_2(f(t))}$. (Received September 09, 2013)

1096-05-757 **Relinde Jurrius*** (relinde.jurrius@vub.ac.be), Vrije Universiteit Brussel, Belgium, and **Ruud Pellikaan** (g.r.pellikaan@tue.nl), Eindhoven University of Technology, Netherlands. *Application of hyperplane arrangements to weight enumeration.*

Many research in coding theory is focussed on linear error-correcting codes. Since these codes are subspaces, linear algebra plays a prominent role in studying them.

An important polynomial invariant of linear error-correcting codes is the (extended) weight enumerator. The weight enumerator gives information about the probability of undetected errors in error-detection, and about the probability of decoding errors in bounded distance decoding. Furthermore, the extended weight enumerator is equivalent to the Tutte polynomial of the matroid associated to the code.

Linear codes are closely connected to hyperplane arrangements: the columns of the generator matrix of a code can be viewed as the coordinates of a hyperplane arrangement over a finite field. Using this correspondence, the problem of determining the extended weight enumerator can be transformed into a counting problem on a hyperplane arrangement. In fact, the extended weight enumerator is equivalent to the coboundary polynomial (or two-variable characteristic polynomial) of the associated hyperplane arrangement.

In this talk, we will examine this application of hyperplane arrangements to weight enumeration in more detail. The practical use of the theory will be motivated by several examples. (Received September 10, 2013)

1096-05-784 **Katherine Edwards*** (ke@princeton.edu), Dept. of Computer Science, 35 Olden Street, Princeton, NJ 08544, and **Jan van den Heuvel**, **Ross J Kang** and **Jean-Sebastien Sereni**. *Extensions from precoloured sets of edges.*

We consider precolouring extension problems for edge-colouring, in an attempt to prove strengthenings of Shannon's and Vizing's theorems. In particular, we are interested in extending a colouring from an arbitrarily precoloured matching using a minimum number of colours and conjecture that in general, $\Delta+1$ colours suffice. We overview some progress toward this conjecture and some of its generalizations, and discuss the proof for some classes of graphs. This question turns out to have close connections with the notorious list colouring conjecture as well as other classical notions of choosability. (Received September 10, 2013)

1096-05-786 **Hal Kierstead** and **Landon Rabern*** (landon@lbd-data.com). *Extending Alon-Tarsi Orientations.*

We prove that a graph either has many edges or an Alon-Tarsi orientable induced subgraph satisfying a certain degree condition. From this we get improved lower bounds on the number of edges in list critical and online list critical graphs. This is joint work with Hal Kierstead. (Received September 10, 2013)

1096-05-824 **Elizabeth Kelley***, Department of Mathematics, Harvey Mudd College, Claremont, CA 91711, **Francis Edward Su**, Department of Mathematics, Harvey Mudd College, Claremont, CA 91711, and **Patrick Tierney**, Department of Mathematics, Harvey Mudd College, Claremont, 91711. *A Combinatorial Approach to the Meunier-Babson Theorem.*

We present a constructive combinatorial approach to the Meunier-Babson theorem, a generalization of the classical Sperner's Lemma that allows triangulated simplices to have multiple labellings, and asserts the existence of elementary simplices with particular labelling schemes. Our path-following argument solves, and offers a strengthened result for, particular cases of the theorem. This strengthening allows the Meunier-Babson theorem to be applied to questions of fair division, such as rental harmony or cake cutting. (Received September 10, 2013)

1096-05-854 **Jessica E Ginepro*** (jessginepro@yahoo.com), 136 Donbray Road, Springfield, MA 01119, and **Thomas C Hull**. *The Origami Miura Map Fold and Graph Colorings.*

The Origami Miura Map fold is a crease pattern in which each vertex looks like a bird's foot, with two congruent obtuse angles and two congruent acute angles. Each vertex has a mountain-valley assignment, only some of which are valid, meaning possible to fold without tearing our paper. Our goal is to count how many ways we can fold a $N \times M$ Miura Map fold. In this talk we will discuss how the number of locally flat-foldable mountain-valley assignments of a $N \times M$ Miura Map fold is equal to the number of proper 3-colorings of a $(N+1) \times (M+1)$ grid graph with one vertex precolored. This research is supported by NSF grant EFRI-1240441. (Received September 10, 2013)

1096-05-855 **Glenn Hurlbert*** (hurlbert@asu.edu), Arizona State University, School of Mathematics and Statistics, Tempe, AZ 85287-1804. *EKR on Graphs and Lattices.*

The classic theorem of Erdős, Ko, and Rado has generated a lot of activity in recent years. One new idea explores the structure of intersecting families of maximum size under the restriction that certain pairs of elements cannot be in the same set. This corresponds to investigating the largest intersecting family of independent sets of a graph. If some such family forms a star – some element is in every set – the graph is said to have the EKR property. A second consideration studies intersection of other objects, such as permutations and partitions (defined by sharing the same coordinate or block, respectively), and asking the usual Erdős-Ko-Rado and Hilton-Milner type questions. A third notion defines the intersection of elements of a lattice by to the rank of their meet. Here, a lattice is said to be EKR if a largest intersecting family of elements forms a star; that is, it is the upset of an atom. We discuss current advances in these areas, including joint work with Bekmetjev, Brightwell, Czygrinow, Fishel, Kamat, and Meagher. (Received September 10, 2013)

1096-05-863 **D. Jacob Wildstrom*** (dwildstr@erdos.math.louisville.edu), 328 Natural Sciences Building, Department of Mathematics, University of Louisville, Louisville, KY 40292. *More Granny, Less Square: Methods for center-worked polyomino designs.*

A granny square is an example of a center-worked design, where material is built in rounds around a central point. If we replace this point with a one-dimensional "spine", polyominoes can be built using the same fundamental design process as is used in the granny square. However, certain polyominoes require different crafting techniques, generalizing the concept of a spine in order to be successfully built in the round. These generalized spinal techniques lead to several classifications for polyominoes according to their "crochetability", and enumerations of the polyominoes in each class. The complications of exploring spinal character for polyhexes and polyiamonds will also be explored. (Received September 10, 2013)

1096-05-865 **Vivek Dhand*** (vivek.dhand@gmail.com). *An order-preserving analogue of O'Hara's structure theorem for Young's lattice.*

Young's lattice $L(m,n)$ consists of integer partitions having at most m parts of size at most n, ordered by inclusion of Young diagrams. K. O'Hara gave the first constructive proof of the unimodality of the Gaussian polynomials by expressing the underlying ranked set of $L(m,n)$ as a disjoint union of products of centered rank-unimodal subsets. We construct a finer decomposition which is compatible with the partial order on Young's lattice, at the cost of replacing the cartesian product with a more general poset extension. As a corollary, we obtain an explicit chain decomposition which exhibits the rank-unimodality of $L(m,n)$ in the following sense: the chains of a given length have the property that their set of highest rank elements comes equipped with a rank-preserving embedding into $L(m',n')$, for some $m' < m$ and $n' < n$, and the subposet induced by the image has a chain decomposition of the same form. (Received September 10, 2013)

1096-05-873 **Oliver R Knill*** (knill@math.harvard.edu), Department of Mathematics, One Oxford Street, Cambridge, MA 02138. *Classical mathematical structures within topological graph theory.*

Finite simple graphs are a playground for classical areas of mathematics. We illustrate this by looking at theorems in topology (i.e. homotopy, category, fixed point theorems), geometry (i.e. Gauss Bonnet, Poincare-Hopf, Riemann-Hurwitz) analysis (zeta functions,extremal problems), differential equations (i.e. heat or wave equations, integrable systems),linear algebra (i.e. spectral perturbation, Hodge theory, isospectral graphs) or combinatorics (simplex combinatorics, matrix tree theorems). (Received September 17, 2013)

1096-05-882 **Andrzej Czygrinow**, **Louis DeBiasio**, **H.A. Kierstead** and **Theodore Molla*** (molla@illinois.edu). *Minimum degree thresholds for spanning subgraphs of directed and oriented graphs.* Preliminary report.

Many theorems in extremal graph theory have the following form: If the minimum vertex degree of a graph G, denoted as $\delta(G)$, is at least some fraction of the order of the graph, then G contains a specified spanning subgraph. For instance, the Hajnal-Szemerédi Theorem states that if G is a graph on ks vertices and $\delta(G) \geq (s-1)k$, then G contains k vertex disjoint copies of the complete graph on s vertices. Similarly, Dirac's Theorem states that if $\delta(G) \geq |G|/2$ and $|G| \geq 3$ then G contains a Hamilton cycle. This talk will explore analogues of these two celebrated theorems in directed graphs, oriented graphs and weighted graphs.

For example, we believe that if $s \geq 4$, G is a directed graph on ks vertices and $\delta(G) \geq 2(s-1)k-1$, then G can be partitioned into k vertex disjoint subgraph of size s, each of which contains every tournament on s vertices. We can prove that this is asymptotically true provided s is sufficiently large. (Received September 10, 2013)

1096-05-885 **Jozsef Balogh**, **Ping Hu**, **Bernard Lidicky*** (lidicky@illinois.edu), **Oleg Pikhurko**, **Balazs Udvari** and **Jan Volec**. *Use of flag algebras with permutations.*

Flag algebras are recently developed tools with many successful applications when considering maximal or minimal densities of fixed graphs in family of graphs. The concept can be also applied for other settings like hypergrpahs, hypercubes or permutations where we show some progress. (Received September 10, 2013)

1096-05-892 **Carl R Yerger*** (cayerger@davidson.edu), Department of Mathematics, Box 7059, Davidson, NC 28035, and **Kyle Yang**. *Steinberg's Conjecture, the Bordeaux Coloring Conjecture and Near-Coloring.*

An important result in the theory of graph coloring is Grotzsch's theorem, which states that every triangle-free planar graph is 3-colorable. A famous related question is due to Steinberg and states that any planar graph without 4- or 5-cycles is 3-colorable. In this talk, we will discuss some of the recent progress made towards proving Steinberg's conjecture and discuss joint work with Ken-ichi Kawarabayashi that planar graphs with no 5-cycles, 6-cycles or intersecting triangles are 3-colorable. In addition, we discuss recently completed senior thesis work based on near-coloring with Kyle Yang. (Received September 11, 2013)

1096-05-895 **Xingxing Yu*** (yu@math.gatech.edu) and **Baogang Xu** (baogxu@njnu.edu.cn). *On Judicious Bisections of Graphs.*

A bisection of a graph G is a bipartition S_1, S_2 of $V(G)$ such that $||S_1| - |S_2|| \leq 1$. It is NP-hard to find a bisection S_1, S_2 maximizing $e(S_1, S_2)$ (repectively, minimizing $\max\{e(S_1), e(S_2)\}$), where $e(S_1, S_2)$ denotes the number of edges from S_1 to S_2, and $e(S_i)$ denotes the number of edges of G with both ends in S_i. There has been extensive research on bisections from algorithmic point of view, but very few extremal results are known. Bollobás and Scott conjectured that if G is a graph with m edges and minimum degree at least 2 then G admits a bisection S_1, S_2 such that $e(S_i) \leq m/3$ for $i = 1, 2$. In this paper, we confirm this conjecture and show that the triangle is the only extremal graph. Joint work with Baogang Xu. (Received September 11, 2013)

1096-05-923 **Alfred W Hales*** (hales@ccrwest.org), Center for Communications Research, 4320 Westerra Court, San Diego, CA 92121. *Two Problems: Generation and Presentation.*

Consider the set $\mathrm{D} = \mathrm{D}_n$ of all de Bruijn sequences of length 2^n, where we distinguish between cyclic rotations of a sequence. Then D_n has cardinality $2^{2^{(n-1)}}$.

Problem 1: Find an efficient explicit bijection between D_n and the set of all $2^{(n-1)}$ long binary sequences, one requiring minimal computation time and memory.

Problem 2: Suppose S is a subset of D_n. Determine the structure of the group generated by elements x,y with one relation for each sequence s in S - where the relation corresponding to a sequence s comes from replacing each 0 in s by x and each 1 by y.

For $\mathrm{S} = \mathrm{D}_n$ we know the answer by a result of Rosenberg. We are particularly interested in the case where S is the set of sequences obtained from maximal length shift register sequences by inserting an extra 0. (Received September 11, 2013)

1096-05-1001 **Carolyn A Yackel*** (yackel_ca@mercer.edu). *Families of p4m Knitted Square Tiles.* Preliminary report.

A fashionable and seam-reducing way to create knitted rectangles is to knit squares in the round. We can achieve a p4m (*442) motif by having each square consist of eight reflected isosceles right triangular fundamental domains; see, for example, Templeton squares. If the fundamental-domain triangle is decorated by a single arc connecting two edges, we can consider the resulting square to have an "inside color" and an "outside color." Simple modifications to this arc produce a family of square patterns. We discuss a method for obtaining a corresponding family of square knitting pattern instructions. The squares in our family can be assigned greyscale values and subsequently used to approximate photographs or create interesting visual images, somewhat like the modified Truchet Tiles of Bosch and Collier. (Received September 12, 2013)

1096-05-1004 **James M. Carraher*** (s-jcarrah1@math.unl.edu), **Stephen G. Hartke** and **Paul Horn**. *Rainbow spanning trees in complete graphs.*

Let G be a properly edge-colored copy of the complete graph K_n. A rainbow spanning tree of G is a spanning tree where each edge has a different color. Brualdi and Hollingsworth and Kaneko, Kano, and Suzuki conjectured that every properly edge-colored complete graph K_n ($n \geq 5$) has $\lfloor n/2 \rfloor$ edge-disjoint rainbow spanning trees. We show that for sufficiently large n that every properly edge-colored K_n contains at least $\lfloor n/(1000 \log n) \rfloor$ edge-disjoint rainbow spanning trees. (Received September 12, 2013)

1096-05-1010 **Michael D. Barrus*** (barrus@math.byu.edu), Department of Mathematics, Brigham Young University, Provo, UT 84602. *Uniqueness and minimal obstructions for tree depth.*

The tree depth of a graph G is the smallest natural number k for which there exists a coloring of the vertices of G with values from $\{1, \dots, k\}$ such that any path joining two vertices with the same color must contain a vertex having a color of higher value. The graph G is k-critical if it has tree depth k and every proper minor of G has smaller tree depth.

We define a graph G to be 1-*unique* if for every vertex v in G, there exists an optimal ranking of G in which v is the unique vertex with label 1. We show that several classes of k-critical graphs are 1-unique, and we conjecture that the property holds for all k-critical graphs. Generalizing a previously known construction for trees, we exhibit an inductive construction that uses 1-unique k-critical graphs to generate large classes of critical graphs having a given tree depth. (Received September 12, 2013)

1096-05-1012 **Jonathan Novak*** (jnovak@math.mit.edu), 77 Massachusetts Avenue, Boston, MA 02139. *From Kontsevich-Witten to (monotone) Hurwitz via HCIZ.*

The Kontsevich-Witten theorem asserts that two different approaches to 2D gravity are equivalent. The first approach involves the asymptotic analysis of random matrix partition functions, while the second involves intersection theory in moduli spaces of Riemann surfaces. The intersection theory approach can be reduced to a problem about counting walks on the Cayley graphs of the symmetric groups. Quite remarkably, a desymmetrized version of this enumeration problem turns out to be the basic structure underlying the asymptotics of spherical (HCIZ) integrals, which are just Schur functions in disguise. We will discuss two approaches to rigorously constructing the asymptotics of spherical integrals: one using complex analysis and self-interacting random walks on symmetric groups, and the other using loop equations and concentration of measure. Discussion of the first approach is based on joint work with M. Guay-Paquet and I. Goulden, while discussion of the second approach is based on joint work with A. Guionnet. (Received September 12, 2013)

1096-05-1034 **Geir Agnarsson*** (geir@math.gmu.edu), Geir Agnarsson, Department of Math. Sciences, Fairfax, VA 22030. *Induced subgraphs of hypercubes.*

Let Q_k denote the k-dimensional hypercube on 2^k vertices. A vertex in a subgraph of Q_k is *full* if its degree is k. We apply the Kruskal-Katona Theorem to compute the maximum number of full vertices an induced subgraph on $n \leq 2^k$ vertices of Q_k can have, as a function of k and n. (Received September 12, 2013)

1096-05-1061 **Young Soo Kwon*** (ysookwon@ynu.ac.kr), 202-1602 Sawol Hwasung Parkdream Apt., Sinmae-dong, Suseong-gu, Daegu, 706-937, South Korea, and **Istvan Kovacs** (istvan.kovacs@upr.si), , Hungary. *Regular Cayley maps on some groups.*

A map is a cellular embedding of a graph into a surface and a regular map is a highly symmetric map like five Platonic solids. A Cayley map is a cellur embedding of a Cayley graph into an orientable surface having the same cyclic rotation of generators around each vertex. Regular Cayley maps on a given group G are related to skew morphisms of G satisfying some conditions. Using these relations, we will consider several properties of regular Cayley maps on some groups. Furthermore, we give a talk about some recent results related to regular Cayley maps on dihedral groups, for example, classifications of reflexible regular Cayley maps and regular Cayley maps having as many as possible different power values. (Received September 12, 2013)

1096-05-1068 **Stephen J. Graves** and **Mark E. Watkins*** (mewatkin@syr.edu), Syracuse University, Mathematics Department, 215 Carnegie, Syracuse, NY 13244-1150. *Growth Rates of Face-Homogeneous Planar Tessellations.*

A tessellation of the Euclidean or hyperbolic plane is *face-homogeneous* if for some integer $k \geq 3$ there exists a cyclic sequence $\sigma = [p_0, p_1, \ldots, p_{k-1}]$ of integers ≥ 3 such that, for every face f of the tessellation, the valences of the vertices incident with f are given by the terms of σ in either clockwise or counter-clockwise order. When a given cyclic sequence σ is realizable in this way, it may determine a unique tessellation (up to isomorphism), in which case σ is called *unambiguous*, or it may be the valence sequence of two or more nonisomorphic tessellations (*ambiguous*). As tessellations of the hyperbolic plane are well-known to have exponential growth, we seek the face-homogeneous tessellation(s) of the hyperbolic plane of slowest growth and show that the least growth rate of unambiguous face-homogeneous tessellations is the "golden mean" $\gamma = (1+\sqrt{5})/2$ attained by the sequences $[4, 6, 14]$ and $[3, 4, 7, 4]$. An ambiguous sequence may yield nonisomorphic tessellations with different growth rates. However, all such tessellations found thus far have growth rates greater than γ. (Received September 12, 2013)

1096-05-1076 **Jesse Taylor*** (jtjessetaylor@gmail.com). *On matroid minors that guarantee their duals as minors.*

A fundamental operation for matroids is the construction of the dual. This talk solves the problem of determining all 3-connected binary matroids N such that, whenever a 3-connected binary matroid M has an N-minor, and M is large enough, M also has the dual of N as a minor. No previous familiarity with matroids will be assumed. (Received September 12, 2013)

1096-05-1098 **Nathaniel Karst**, **Jessica Oehrlein*** (jessoehrlein@gmail.com), **Denise Sakai Troxell** and **Junjie Zhu**. *$L(d,1)$-labelings of Edge-Path-Replacements by Factorization of Graphs.*

For an integer $d \geq 2$, an $L(d,1)$-labeling of a graph G is a function f from the vertex set to the non-negative integers such that if vertices x and y are adjacent, $|(f(x) - f(y)| \geq d$, and if x and y are at distance two, then $|f(x) - f(y)| \geq 1$. The λ_d-number is the minimum span over all $L(d,1)$-labelings of G. For an integer $k \geq 2$, an edge-path-replacement of G or $G(P_k)$ is the graph obtained by replacing each edge of G with a path on k vertices. We show that the edges of G can be colored using $\lceil \Delta(G)/2 \rceil$ colors so that each monochromatic subgraph has maximum degree at most 2, and we use this fact to provide general upper bounds for $\lambda_d(G(P_k))$ for $k \geq 4$. As a corollary, we settle a conjecture by Lü concerning $\lambda_2(G(P_4))$ and show that the class of graphs $G(P_k)$ with $k \geq 4$ satisfies a conjecture by Havet and Yu on $(d,1)$-total labeling of graphs. (Received September 12, 2013)

1096-05-1099 **Sarah Spence Adams**, **Noura Howell**, **Nathaniel Karst**, **Denise Sakai Troxell** and **Junjie Zhu*** (junjie.zhu@students.olin.edu). *On the $L(2,1)$-Labelings of Amalgamations of Graphs.*

The problem of assigning frequencies to transmitters in a radio network can be modeled through vertex labelings of a graph, wherein each vertex represents a transmitter and edges connect vertices whose corresponding transmitters are operating in close proximity. In one such model, an *$L(2,1)$-labeling* of a graph G is employed, which is an assignment f of nonnegative integers to the vertices of G such that if vertices x and y are adjacent, $|f(x) - f(y)| \geq 2$, and if x and y are at distance two, $|f(x) - f(y)| \geq 1$. The λ-number of G is the minimum span over all $L(2,1)$-labelings of G. Informally, an *amalgamation* of two graphs G_1 and G_2 along a fixed graph G_0 is the simple graph obtained by identifying the vertices of two induced subgraphs isomorphic to G_0, one of G_1 and the other of G_2. We provide upper bounds for the λ-number of the amalgamation of graphs along a given graph by determining the exact λ-number of amalgamations of complete graphs along a complete graph. We also provide the exact λ-numbers of amalgamations of rectangular grids along a path, or more specifically, of the Cartesian products of a path and a star with spokes of arbitrary lengths. (Received September 12, 2013)

1096-05-1141 **Michael S. Jacobson*** (mjacobso@nsf.gov). *Odd and Even Cycle Lengths in Graphs.*

In this talk we will look at a number of results pertaining to the cycle spectrum, the set of cycle lengths, for graphs having certain properties. In particular, several problems and results will be presented about the order of the cycle spectrum and "new" results about the existence of "long" cycles of odd and even length will be given. (Received September 13, 2013)

1096-05-1152 **Antonio Breda d'Azevedo*** (breda@ua.pt), Department of mathematics, University of Aveiro, 3810-747 Aveiro, Portugal. *Pseudo-orientability versus orientability.*

Despite not being a topological property, pseudo-orientability (introduced by Steve Wilson in the eighties) shows interesting resemblances with orientability in respect to maps (cellular embeddings of "multiple" graphs on compact connected surfaces). In this talk we empathise their similarities and differences. (Received September 13, 2013)

1096-05-1156 **Joan P Hutchinson*** (hutchinson@macalester.edu), Department of Mathematics, Macalester College, St. Paul, MN 55105. *Some of my (and other people's) favorite conjectures on chromatic topological graph theory.* Preliminary report.

We present some conjectures on 3-coloring and list-coloring particular families of graphs on the sphere. We also consider some questions on (vertex-) coloring and list-coloring general graphs on nonplanar surfaces. These conjectures and questions have been posed by M.O. Albertson, R.B. Richter, I. Streinu, S. Wagon, and myself, among others. (Received September 13, 2013)

1096-05-1157 **Sarah K Mason*** (masonsk@wfu.edu) and **Robert Jason Parsley**. *A geometric interpretation of the weighted games poset.* Preliminary report.

A weighted game is a situation in which each player carries a certain amount of weight, and a coalition can pass a motion once their combined weight meets or exceeds a certain quota. We introduce a polytope associated to the partially ordered set of weighted games and show that vertical lines in the polytope correspond to saturated chains in the partially ordered set. We use properties of the poset to prove geometric results (such as facet enumerations) about the polytope. (Received September 13, 2013)

1096-05-1187 **Brett C. Smith*** (bcsmith@wesleyan.edu), Wesleyan Dept. of Mathematics and CS, Science Tower 655, 265 Church Street, Middletown, CT 06459. *Planar Graphs of Fixed Tree Width.* Preliminary report.

In their series of papers, Graph Minors, Robertson and Seymour introduce a tree decomposition of a graph. This definition leads to a useful graph property called tree width. The $n \times n$-grid graph is the classical example of a planar graph of tree width n. We prove this graph is not minimal in the sense that it contains a proper minor which also has tree width n, and we characterize the edges in the $n \times n$-graph whose removal reduces the tree width. Furthermore, we prove that the n-triangular-grid graph also has tree width n. These graphs provide insight into the family of minor-minimal planar graphs of tree width n. (Received September 13, 2013)

1096-05-1203 **Michael Ferrara*** (michael.ferrara@ucdenver.edu). *Colored Saturation Problems.*

Let $\mathcal{F}$ be a family of t-edge-colored graphs. An edge-colored graph G is $(\mathcal{F}, t)$-saturated if G contains no member of $\mathcal{F}$ as a subgraph, but the addition of any edge $e \in \overline{G}$ in any color $i \in [t]$ creates a copy of some $F \in \mathcal{F}$.

In this talk, we will discuss some results on $(\mathcal{F}, t)$-saturated graphs of fixed order with minimum size, in particular focusing on the case where $\mathcal{F}$ consists of all possible rainbow colorings of a given graph H. We will also share some results on a related problem inspired by Hanson and Toft's 1987 conjecture on the traditional (uncolored) saturation number for $(K_{t_1}, \ldots, K_{t_k})$-Ramsey-minimal graphs.

This work is joint with a number of coauthors. (Received September 13, 2013)

1096-05-1226 **Solomon W Golomb*** (sgolomb@usc.edu), 3740 McClintock Ave, EEB 504A, Los Angeles, CA 90089-2565. *Modified de Bruijn Sequences and* m*-Sequences.* Preliminary report.

The *de Bruijn sequences of degree* n are binary sequences of period 2^n in which every possible binary vector of length n occurs exactly once per period. In each period there are 2^{n-2} runs of 1's alternating with 2^{n-2} runs of 0's. These include one run of n 1's and one run of n 0's, plus 2^{n-k-2} runs of length k of each type for $1 \leq k \leq n-2$. As shown by N.G. de Bruijn (and earlier by C. Flye Sainte-Marie), there are $2^{2^{n-1}-n}$ cyclically distinct de Bruijn sequences of degree n.

A *modified de Bruijn sequence of degree* n results when a single 0 is omitted from the longest run of 0's, leaving a sequence of period $2^n - 1$, with the same run lengths as above except for a single run of $n-1$ 0's in place of a single run of n 0's. There are (still) $2^{2^{n-1}-n}$ such sequences of degree n.

The "m-sequences" (binary sequences of period $2^n - 1$ obtained from an n-stage linear shift register with feedback) of degree n form a subset of modified de Bruijn sequences of degree n.

An unsolved problem is to settle the conjecture that the m-sequences are the only modified de Bruijn sequences with the two-level autocorrelation property, for every degree $n \geq 1$. (Received September 13, 2013)

1096-05-1259 **Wilfried Imrich*** (imrich@unileoben.ac.at), Mathematics and Information Technology, Montanuniversitaet Leoben, 8700 Leoben, Austria. *Symmetry breaking in graphs.*

A coloring of the vertices of a graph G is called distinguishing if the stabilizer of the coloring in the automorphism group of G is trivial. Tom Tucker conjectured that, if every automorphim of a connected, locally finite graph moves infinitely many vertices, then there exists a distinguishing 2-coloring, that is, a distinguishing coloring using only two colors. This is known as the Infinite Motion Conjecture. Despite many intriguing partial results, it is still open in general.

This conjecture, its generalizations to uncountable graphs, to groups acting on structures, and to endomorphims of graphs, has become my favorite group of conjectures.

In this talk I will present such generalizations of the Infinite Motion Conjecture, with emphasis on uncountable graphs. I will also shortly describe some of the methods used to obtain solutions for various classes of graphs. (Received September 14, 2013)

1096-05-1264 **Abbas Alhakim**, **Steve Butler*** (butler@iastate.edu) and **Ron Graham**. *De Bruijn sequences with varying combs.*

De Bruijn sequences are 0-1 sequences of length 2^n which contain each 0-1 sequence of length n precisely once as a consecutive subsequence (where we are allowed to wrap around at the end). In this talk we report on investigations into what happens when we relax the requirement of being consecutive to being in some"comb", including constructions and various enumerations in special cases. (Received September 14, 2013)

1096-05-1278 **Sudipta Mallik*** (smallik@uwyo.edu). *Probabilistic methods for minimum skew rank of graphs.*

The zero-nonzero pattern of a skew-symmetric matrix defines a graph. The minimum rank of all real skew-symmetric matrices with a given graph is studied. Probabilistic methods are applied to show that for sufficiently large n, there is a graph G of order n for which every skew-symmetric matrix with graph G has rank at least 6, thereby settling an open problem. It is also proved that almost all graphs on n vertices do not allow a skew-symmetric matrix whose rank is more than $\frac{n}{25}$. (Received September 14, 2013)

1096-05-1282 **Joseph Chaffee*** (chaffjr@auburn.edu) and **Chris Rodger**. *A New Proof on the Characterization of Neighborhood Graphs in Maximum Packings of $2K_n$.*

In any partial triple system (V, B) of λK_n, the neighborhood of a vertex v is the graph induced by the multiset of edges $\{\{x, y\} \mid \{v, x, y\} \in B\}$.

In 1987, Colbourn and Rosa showed that for any 2-regular graph Q on $n-1$ vertices, a 2-fold triple system on n vertices could be constructed such that the neighborhood of some vertex was Q unless $(n, Q) \in \{(6, C_2 \cup C_3), (7, C_3 \cup C_3)\}$.

In 2013, the authors showed that if $n \equiv 2 \pmod 3$, then for any 2-regular graph Q on $n-1$ or $n-2$ vertices, there exists a maximum packing of $2K_n$ such that the neighborhood of some vertex is Q unless $(n, Q) = (5, C_2 \cup C_2)$.

The techniques used in the proofs of the two results, while somewhat similar, are different enough that neither seems to be able to handle all three cases ($n \equiv 0, 1, 2 \pmod 3$).

In this talk, the authors give an outline of a new proof of these results which handles all three cases. The proof relies heavily on a recent theorem due to Bryant, Horsley, and Pettersson on the decomposition of K_n into cycles. (Received September 14, 2013)

1096-05-1288 **Ruth Haas**, **Karen Lovejoy**, **Loren Santana** and **Jennifer Tripp***, Department of Mathematics, Smith College, Northampton, MA 01063, and **Cloie Webster**. *Avoiding monochromatic equations in groups.* Preliminary report.

The well studied n-Rado number, $L(n)$, is the least integer such that in every coloring of $\{1, 2, \ldots, L(n)\}$ with n colors there exists a monochromatic solution to $a + b = c$ in $\mathbb{Z}$. In this talk we consider a related question for different groups. For a given finite group G, how many colors are needed so that there is a way to assign each member of G a color so that the equation $a + b = c$ has no monochromatic solution? (Received September 14, 2013)

1096-05-1291 **Caitlyn Hannum**, **Christine Hoffman** and **Katherine Koch*** (kkoch@smith.edu), Department of Mathematics, Smith College, Northampton, MA 01063, and **Erin Linebarger**, **Joseph O'Rourke** and **Judy Wang**. *Developing surfaces that are hulls of two circles in space.*

The convex hull of two circles in space is a shape that consists of developable surface patches, and so can be constructed by cutting out planar pieces and bending and gluing them together to form the shape. We investigate which pairs of circles lead to single-piece developments that do not self-overlap in the plane, and so can be constructed with one cutout. We determine the developments in a number of special placements of the two circles, and formulate conjectures for generalizations. We will display models of these shapes made with a 3D printer and a laser cutter. (Received September 14, 2013)

1096-05-1292 **Ruth Haas***, Department of Mathematics, Smith College, Northampton, MA 01063.
Conjectures and questions in graph reconfiguration.

The reconfiguration problem asks whether one feasible solution to a problem can be transformed into another by some allowable set of moves, while maintaining feasibility at all steps. These can be studied via the reconfiguration graph in which the vertices are the feasible solutions, and two solutions are adjacent if and only if one can be obtained from the other by one application of a specific reconfiguration rule. In this talk we will look at conjectures and motivating questions about reconfiguration in graph coloring and graph domination. (Received September 14, 2013)

1096-05-1293 **Kassie Archer*** (kassie.r.archer.gr@dartmouth.edu). *Descents of λ-unimodal cyclic permutations.*

Let $\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_k)$ be a composition of n. A λ-unimodal permutation π is a concatenation of k unimodal segments of lengths λ_i for all $1 \le i \le k$. For example, $\pi = 149652387$ is a $(6,3)$-unimodal permutation because it is concatenation of a unimodal segments 149652 and 387.

I will present an identity conjectured by Roichman and Adin about the descent set of λ-unimodal cycles, the proof of which involves a relationship between these permutations and words. Additionally, I will discuss some of the motivation and consequences of the identity from representation theory. (Received September 14, 2013)

1096-05-1300 **Stanisław P. Radziszowski*** (spr@cs.rit.edu), Department of Computer Science, Rochester Institute of Technology, Rochester, NY 14623. *Folkman Numbers: Some Results and Open Questions.*

We discuss a branch of Ramsey theory concerning edge and vertex Folkman numbers and how computational techniques can solve some problems therein. We write $G \to (a_1, \ldots, a_k; r)^e$ if for every edge k-coloring of an undirected simple graph G not containing K_r, a monochromatic K_{a_i} is forced in color i for some $i \in \{1, \ldots, k\}$. The edge Folkman number is defined as $F_e(a_1, \ldots, a_k; r) = \min\{|V(G)| : G \to (a_1, \ldots, a_k; r)^e\}$. Vertex Folkman numbers $F_v(a_1, \ldots, a_k; r)$ are defined similarly, except that we color vertices instead of edges.

$F_e(3, 3; 4)$ involves the smallest parameters for which the problem is open, and its value is the answer to the question "What is the smallest order N of a K_4-free graph, for which any edge 2-coloring must contain at least one monochromatic triangle?" It is known that $19 \le N \le 786$. We will present the background, overview related problems, and give some evidence why it is likely that $N < 100$.

For the vertex Folkman numbers, the case of special interest is $F_v(2_k; r)$, which is the order of the smallest $(k+1)$-chromatic K_r-free graph. All $F_v(2_k; r)$ are known for $k \le r+1$. We will overview the results for $k \le r+1$ and present some of the open cases for $k \ge r+2$. (Received September 14, 2013)

1096-05-1310 **Corrine Previte*** (previte@math.colostate.edu). *Homology of the D-Neighborhood Complex of Graphs.* Preliminary report.

Consider a simple graph G with diameter d. Let D be a subset of $\{0, 1, \ldots, d\}$. For each vertex $u \in G$, let N_u be the simplex consisting of all vertices whose graph distance from u lies in D. We refer to N_u as the D-neighborhood of u. The D-neighborhood complex of G, denoted $C(G, D)$, is the simplicial complex generated by the D-neighborhoods of vertices in G. We relate properties of the graph G with the homology of the chain complex associated to $C(G, D)$. (Received September 14, 2013)

1096-05-1315 **Cun-Quan Zhang***, Math. Dept., West Virginia University, Morgantown, WV 26506-6310. *Tutte's 5-flow conjecture and Jaeger's modulo 5-orientation.*

Let G be a graph with an orientation D. A mapping $f\colon E(G) \mapsto Z_k - \{0\}$ is called *a nowhere-zero k-flow* if, for every vertex $v \in V(G)$,

$$\sum_{e \in E^+(v)} f(e) \;\equiv\; \sum_{e \in E^-(v)} f(e) \pmod{k}.$$

The integer flow problem is a dual of the vertex coloring problem: it is pointed out by Tutte that a planar graph G admits a nowhere-zero k-flow if and only if G is k-face-colorable. Tutte (1954) conjectured that *every bridgeless graph admits a nowhere-zero 5-flow.* Jaeger (1988) pointed out that *if every 9-edge-connected graph has a modulo 5-orientation D (that is, for every vertex $v \in V(G)$, $d_D^+(v) \equiv d_D^-(v) \pmod 5$), then every bridgeless graph admits a nowhere-zero 5-flow.* It is first proved by Thomassen (2012) that *every 55-edge-connected graph has a modulo 5-orientation.* This result is further improved recently that *every 12-edge-connected graph has a modulo 5-orientation.* (Joint work with M. Lovász, C. Thomassen, Y. Wu.) (Received September 14, 2013)

1096-05-1316 **Cun-Quan Zhang***, Math. Dept., West Virginia University, Morgantown, WV 26506-6310. *Circuit double cover conjecture.*

Circuit double cover conjecture: *Every bridgeless graph has a family $\mathcal{F}$ of circuits such that every edge is contained precisely two members of $\mathcal{F}$.* This talk will survey some old and new results to this open problem. (Received September 14, 2013)

1096-05-1318 **Thomas W. Tucker*** (ttucker@colgate.edu), Po Box 163, Sagamore Beach, MA 02562. *Skew morphisms and group factorizations.* Preliminary report.

A skew morphism of a group A is a permutation ϕ of A fixing the identity such that for any $a \in A$ there is an integer $\pi(a)$ such that $\phi(ab) = \phi(a)\phi^{\pi(a)}(b)$ for all $b \in A$. An automorphism is the case where $\pi(a) = 1$ for all a. Given a group factorization AY where $Y = \langle y \rangle$ and $A \cap Y = \{1\}$, left multiplication by y defines a skew morphism $ya = \phi(a)y^{\pi(a)}$, and, conversely any skew morphism defines a factored group $G = AY$. Their introduction and study were motivated by the observation that rotation about the identity of a regular Cayley map for A is a skew morphism. We present a number of new techniques for skew morphisms using the group-factorization viewpoint. This allows short, elementary proofs of work by Kovacs and Nedela on cyclic groups. Other results include that all skew morphisms of an elementary abelian 2-group are automorphisms and that any map skew morphism for the cyclic group C_n preserves all subgroups when n is odd and all subgroups of order dividing $n/2$, when n is even. (Received September 14, 2013)

1096-05-1319 **Thomas W. Tucker*** (ttucker@colgate.edu), PO Box 163, Sagamore Beach, MA 02562. *The infinite motion conjecture.* Preliminary report.

A graph G has distinguishing number 2, written $D(G) = 2$, if its vertices can be 2-colored (not necessarily properly) so that the only automorphism preserving the colors is the identity. For finite G, it is known that when the elements of $Aut(G)$ move enough vertices compared to the size of $Aut(G)$, then $D(G) = 2$. The Infinite Motion Conjecture (IMC) for a locally finite, connected graph G is that "enough" is infinitely many. It is true for many cases: for example, when $Aut(G)$ is primitive or countable, when G is a tree, or when G has sub-exponential growth. The conjecture appears to be connected more to the logic and topology of infinite permutation groups than graph theory: a counterexample to the same conjecture for directed, non-locally finite graphs uses a version of Cantor's back-and-forth argument for countable dense linear orders without endpoints. This talk will survey what is known about the IMC and its variations. (Received September 17, 2013)

1096-05-1337 **Wilfried Imrich*** (imrich@unileoben.ac.at), Mathematics and Information Technology, Montanuniversitaet Leoben, 8700 Leoben, Austria. *Infinite regular median graphs.*

Median graphs are generalizations of trees and can be characterized as retracts of hypercubes. Whereas hypercubes are the only regular (isovalent) finite median graphs, the structure of infinite median graphs is very rich.

This talk gives a survey of different types of regular median graphs by degree, growth, number of ends, and vertex transitivity.

Particular attention is given to recent results, methods of proof, and open problems. (Received September 15, 2013)

1096-05-1408 **Tom Halverson*** (halverson@macalester.edu), Macalester College, Saint Paul, MN 55104, and **Arun Ram** and **Nathaniel Thiem**. *A q-analog of the partition algebra.* Preliminary report.

The partition algebra $P_k(n)$ is the centralizer of the symmetric group S_n acting on the k-fold tensor product $V^{\otimes k}$ of its n-dimensional permutation representation V. The module $V^{\otimes k}$ is isomorphic to the module given by k iterations of restriction and induction between S_n and S_{n-1}. We study the analogous centralizer algebra $Q_k(n,q)$ given by k iterations of Harish-Chandra restriction and induction between finite general linear groups $GL_n(\mathbb{F}_q)$ and $GL_{n-1}(\mathbb{F}_q)$. Then $Q_k(n,q)$ is a q-analog of the partition algebra $P_k(n)$. (Received September 15, 2013)

1096-05-1418 **Cheryl Grood**, **Johannes Harmse**, **Leslie Hogben**, **Thomas J. Hunter**, **Bonnie Jacob*** (bcjntm@rit.edu), **Andrew Klimas** and **Sharon McCathern**. *The minimum rank of the set of symmetric zero-diagonal matrices associated with a graph.*

Associated with any simple graph G is a family of symmetric zero-diagonal matrices with the same zero-nonzero pattern as the adjacency matrix of G. The minimum rank of the matrices in this family is denoted $\mathrm{mr}_0(G)$. It turns out that there is a strong connection between the ranks of these matrices and the generalized cycles that exist as subgraphs of G.

In this talk, we characterize all connected graphs G with $\mathrm{mr}_0(G) \leq 3$, as well as all connected graphs with $\mathrm{mr}_0(G) = |V(G)|$. In fact, $\mathrm{mr}_0(G) = |V(G)|$ if and only if G has a unique spanning generalized cycle, also known as a unique perfect $[1,2]$-factor, among other names. We go on to present an algorithm for determining whether a graph has a unique spanning generalized cycle. We also determine the maximum zero-diagonal rank of a graph, also related to generalized cycles, and finally show that there exist graphs G for which some ranks between $\mathrm{mr}_0(G)$ and the maximum zero-diagonal rank of G cannot be realized. (Received September 15, 2013)

1096-05-1433 **Glenn Hurlbert*** (hurlbert@asu.edu), Arizona State University, School of Math. & Stat. Sci., Tempe, AZ 85287-1804, and **Victoria Horan** (victoria.horan.1@us.af.mil), Air Force Research Laboratory, Rome, NY 13441. *Overlap Cycles for Steiner Systems.*

Chung, Diaconis, and Graham introduced Universal cycles as a generalization of de Bruijn cycles to combinatorial structures other than m-ary words. For instances not having such cycles, Godbole, Knisley, and Norwood introduced the relaxation of k-overlap cycles, where k measures the overlap size. In their book, *Ordering Block Designs*, Dewar and Stevens outline a number of applications for such listings of the blocks of a design. As an extension of Dewar's result for rank two Universal cycles of Steiner triple systems, we prove the existence of 1-overlap cycles for automorphism free Steiner triple systems of each possible order (for which Steiner triple systems exist). We do the same for Steiner quadruple systems with more than 4 varieties. (Received September 15, 2013)

1096-05-1446 **Colin Gavin** and **Elizabeth Stanhope*** (stanhope@lclark.edu), 0615 SW Palatine Hill Road, Portland, OR 97219, and **Sam Stewart**. *Defining a graph theoretic analog to a Riemannian orbifold.* Preliminary report.

Riemannian orbifolds are a slight generalization of Riemannian manifolds. Instead of being locally diffeomorphic to R^n, Riemannian orbifolds are locally diffeomorphic to R^n modulo the isometric action of a finite group. Recently, a number of authors have examined orbifolds from the perspective of inverse spectral geometry. In light of the strong connection between spectral geometry and spectral graph theory, our project defines a graph theoretic parallel of an orbifold, called an orbigraph, and obtains spectral results about orbigraphs. The spectrum of the adjacency matrix of a k-orbigraph yields bounds on the number of singular (non k-star) vertices present in the orbigraph. The reversibility (as in Markov chains) of an orbigraph determines if it can be obtained as the quotient of a finite k-regular graph. Both the definition of an orbigraph and our results about them are new. (Received September 15, 2013)

1096-05-1447 **Irving Dai*** (ifdai@college.harvard.edu), 64 Linnaean St., 237 Currier Mail Center, Cambridge, MA 02138. *Properties of Full-Flag Johnson Graphs.*

We study a variant of the family of Johnson graphs,the Full-Flag Johnson graphs. We show that Full-Flag Johnson graphs are Cayley graphs on S_n generated by certain classes of permutations, and that they are in fact generalizations of permutahedra. We derive some results about the adjacency matrices of Full-Flag Johnson graphs and apply these to the set of permutahedra to deduce part of their spectra. (Received September 15, 2013)

1096-05-1456 **Milena Hering** and **Josephine Yu***, jyu@math.gatech.edu. *Projective normality for tropical curves.*

We study projective normality for tropical curves. A divisor D is called projectively normal if for every positive integer m, the degree m polynomials on the projective embedding given by D cut out a complete linear system. We define projective normality for tropical curves using tropical modifications and prove that on tropical elliptic curves, any divisor of degree at least 3 is projectively normal. We conjecture that divisors of degree at least $2g+1$ are projective normal, where g is the genus of the tropical curve. (Received September 15, 2013)

1096-05-1459 **Melody Chan***, Department of Mathematics, One Oxford St, Cambridge, MA 02143. *Combinatorics of the tropical moduli space of curves.* Preliminary report.

I'll report on work in progress on computations of the tropical moduli space of curves of genus g with n marked points. This is a certain simplicial complex whose cells are indexed by edge-colored weighted dual graphs of stable algebraic curves. By using tropical geometry and a theorem of Payne, we are able to give new computations of some known results on the top graded pieces of the weight filtration on the cohomology of $\mathcal{M}_{g,n}$. (Received September 15, 2013)

1096-05-1464 **Benjamin P Gunby*** (bgunby@mit.edu). *The Maximal Length of a k-separator Permutation.*

A permutation $\sigma \in S_n$ is a k-separator if all of its patterns of length k are distinct. Let $F(k)$ denote the maximal length of a k-separator. Hegarty showed that $k + \lfloor\sqrt{2k-1}\rfloor - 1 \leq F(k) \leq k + \lfloor\sqrt{2k-3}\rfloor$, and conjectured that $F(k) = k + \lfloor\sqrt{2k-1}\rfloor - 1$. We will strengthen the upper bound to prove the conjecture for all sufficiently large k (in particular, for all $k \geq 282753$). (Received September 15, 2013)

1096-05-1479 **Alex Chin*** (ajchin@ncsu.edu), **Kellie MacPhee** (kellie.j.macphee.14@dartmouth.edu) and **Charles Vincent** (vincentc@lafayette.edu). *Random subtrees of complete graphs.*

Select a subtree of the complete graph K_n uniformly at random. What is the expected number of edges in the subtree, and what is the probability that the subtree is spanning? We answer both questions and discuss how these statistics change when instead considering a weighted probability measure, in which the probability of choosing a subtree is proportional to the size of the subtree. We then define a generating function polynomial that can help answer some open questions. (Received September 15, 2013)

1096-05-1481 **Ethan Berkove**, **David Cervantes Nava**, **Daniel Condon** and **Rachel Katz*** (rachelkatz@uchicago.edu). *The Colored Cubes Problem.* Preliminary report.

Given a palette of $m \leq 6$ colors, we say a cube is m-colored if each face is painted with a single color, and each color appears on at least one face. The number of distinct m-colorings depends on m; for example, $m = 6$ gives rise to 30 distinct cubes up to rigid isometry. An interesting question is to determine the minimum number $k(n)$ so that given an arbitrary collection of $k(n)$ m-colored cubes, it is always possible to assemble a larger $n \times n \times n$ cube where each $n \times n$ face is a single color. In this talk we will discuss work on this problem. We will also discuss related findings on how the 6-coloring relates to the symmetric group on 6 letters. (Received September 15, 2013)

1096-05-1494 **Mohit Singh** and **Hehui Wu*** (noshellwhh@gmail.com). *Demand Matching and Correlated Independent Sets in Trees.*

We consider the demand matching problem where we are given a simple bipartite graph $G = (V, E)$, a demand d_e and profit π_e for each edge $e \in E$ and capacity b_v for each vertex $v \in V$. A subset M of edges is called a demand matching if the sum of demands of edges chosen in M incident at v is at most b_v for each vertex v. The goal of the demand matching problem is to select a demand matching M which maximizes the sum of profit of edges in M.

In this paper we give nearly tight upper and lower bounds on the integrality gap of a natural linear programming relaxation for the problem. We show that the integrality gap of the linear program is closely related to finding probability distributions over independent sets of a tree that satisfy certain marginal as well as pairwise correlations. We give a nearly tight characterization for such distributions. We use this characterization to bound the integrality gap of the linear programming relaxation for the demand matching problem in the interval $[2.6999, 2.7086]$. (Received September 15, 2013)

1096-05-1539 **Martin Downs** and **Gareth A. Jones*** (g.a.jones@maths.soton.ac.uk). *Enumerating regular objects with a given automorphism group.*

The talk will describe how Hall's theory of Möbius inversion in groups allows one to enumerate regular objects such as maps and hypermaps on surfaces, dessins d'enfants, and coverings of topological spaces, with a given finite automorphism group. It will include some new examples in which the automorphism groups are simple Suzuki groups $Sz(q)$. (Received September 16, 2013)

1096-05-1547 **Seiya Negami*** (negami@ynu.ac.jp). *Distinguishing coloring of 3-regular graphs on closed surfaces.*

A coloring of a graph G is said to be distinguishing under a subgroup A in $\mathrm{Aut}(G)$ if any automorphism in A other than the identity map does not preserve the colors. We shall show that a 3-regular 3-connected graph 2-cell embedded on a closed surface has a 4-coloring which is distinguishing under its map automorphism group and uses color 4 only once unless it is one of few exceptions, and present our approach to showing that any "sufficiently large" 3-regular graph on closed surface has a 3-coloring which is distinguishing under its map automorphism group. (Received September 16, 2013)

1096-05-1550 **Ji Young Choi*** (jychoi@ship.edu), 1871 Old Main Dr, Math Dept, Shippensburg, PA 17257. *Vertical recurrence relations for Stirling numbers of the second kind.* Preliminary report.

For positive integers k, m and n, the number of partitions of an n set into k nonempty subsets of size $\leq m$ is defined as the (n,k)-th m-restricted Stirling number of the second kind. Without the restriction m, the (n,k)-th Stirling numbers of the second kind is defined. In this talk, recurrence relations for the m restricted Stirling numbers of the second kind and the Stirling numbers of the second kind, for fixed k, will be presented. (Received September 16, 2013)

1096-05-1553 **Jozef Siran*** (j.siran@open.ac.uk), Mathematics and Statistics, Open University, Milton Keynes, MK7 6AA, United Kingdom. *Non-orientable regular maps of any given type.*

A regular map is a graph embedding with the highest 'level of symmetry', that is, such that the automorphism group of the embedding is transitive (and hence regular) on flags. In a regular map, all vertices have the same degree, say, k, and all face boundaries have the same length, say m; the pair (k,m) is the type of the map.

It is well known that for any given pair (k,m) such that $1/k + 1/m \leq 1/2$ there exist infinitely many finite regular maps of type (k,m) on an orientable surface. This is a consequence of residual finiteness of triangle groups and it has been rediscovered a number of times in the past. A non-orientable analogue of this result was proved only very recently; we will discuss the proof and its implications. (Received September 16, 2013)

1096-05-1555 **Anthony Harkin**, School of Mathematical Sciences, Rochester Institute of Technology, Rochester, NY 14623-5604, and **Darren A Narayan*** (dansma@rit.edu), School of Mathematical Sciences, Rochester Institute of Technology, Rochester, NY 14623-5604. *Modeling functional connectivity of the human brain and gauging the effects of sub-concussive hits on athletes.*

Over the past year the effects of concussions on football players and other athletes has dominated the national media. However, our preliminary data has shown that repeated milder sub-concussive hits can also have a significant effect on brain function. We have used metrics from graph theory to analyze data from functional MRI scans of football players. Our focus will be on resting state functional MRI scans where 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 use several graph theory metrics to analyze functional connectivity of the brain, including characteristic path length, global and local efficiency, clustering coefficent, small-worldness, and betweenness centrality. (Received September 16, 2013)

1096-05-1575 **Megan E. Heenehan*** (heenehanm@easternct.edu), Department of Mathematics & Computer Science, Eastern Connecticut State University, 83 Windham Street, Willimantic, CT 06226, and **Karen L. Collins** (kcollins@wesleyan.edu), Department of Mathematics & Computer Science, Wesleyan University, Middletown, CT 06459. *Minimum degree and immersions of complete graphs.*

In 2003, Abu-Khzam and Langston conjectured that every d-chromatic graph contains an immersion of K_d. This conjecture has been proved for $d = 5, 6, 7$. In each case it is proved that graphs with minimum degree $d-1$ have immersions of K_d. However, for $d \geq 8$ graphs with minimum degree $d-1$ need not have an immersion of K_d. In this talk we will construct infinite families of graphs with minimum degree $d-1$ and no immersion of K_d. We will also discuss a conjecture for the minimum number of vertices a 2-edge-connected graph must have to contain an immersion of K_d. (Received September 16, 2013)

1096-05-1582 **Heather M Russell*** (hrussell2@washcoll.edu). *sl_4 webs.* Preliminary report.

Quantum knot invariants come from interpreting knot diagrams as pictures of intertwiners of quantum group representations. Each diagram can be decomposed as a linear combination of certain basic planar trivalent graphs called webs. We discuss some combinatorial results about sl_4 webs obtained during the Summer 2012 CSU Channel Islands REU. This work is joint with Ernest Guico, Jennifer Kenkel, Acadia Larsen, Briseida Trejo-Escamilla, and Madison Turbeville. (Received September 16, 2013)

1096-05-1585 **Dennis W. Hall*** (dhall15@lsu.edu), 303 Lockett Hall, Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *A Characterization of Tangle Matroids.*

Tangles are used to identify the highly connected parts of graphs and matroids. Given a matroid and a tangle, we can define an associated tangle matroid. This talk gives a new characterization and several structural results for tangle matroids. (Received September 16, 2013)

1096-05-1587 **Georgia Benkart*** (benkart@math.wisc.edu), Department of Mathematics, University of Wisconsin-Madison, 480 Lincoln Drive, Madison, WI 53706. *Walking on Graphs the Representation Theory Way.*

How many walks of n steps are there from point A to point B on a graph? Often finding the answer involves clever combinatorics or tedious treading. But if the graph is the representation graph of a group, representation theory can facilitate the counting and provide much insight. The simply-laced affine Dynkin diagrams are representation graphs of the finite subgroups of the special unitary group SU(2) by the celebrated McKay correspondence. These subgroups are essentially the symmetry groups of the platonic solids, and the correspondence has been shown to have important connections with diverse subjects including mirror symmetry and the resolution of singularities. Inherent in McKay's correspondence is a rich combinatorics coming from the Dynkin diagrams. Some of the ideas involved in seeing this go back to Schur, who used them to establish a remarkable duality between the representation theories of the general linear and symmetric groups. There is a similar duality between the SU(2) subgroups and certain algebras that enable us to count walks and solve other combinatorial problems. In this case, the duality leads to connections with the Temperley-Lieb algebras of statistical mechanics, with partitions, with Catalan numbers, and much more. (Received September 16, 2013)

1096-05-1591 **Dennis Wong*** (cwong@uoguelph.ca). *Gluing universal cycles and de Bruijn sequences.*

We present a simple lemma that describes when two universal cycles can easily be concatenated together to obtain a new universal cycle. This led to the first known efficient universal cycle construction for the set of binary strings of length n with weight (number of 1s) in the range $c, c+1, \ldots, d$ where $0 \leq c < d \leq n$. The famous FKM algorithm can then be viewed as recursively concatenating small universal cycles (aperiodic prefixes) to obtain a universal cycle for the set of length n binary strings. We also demonstrate a simple construction in a similar fashion that constructs the lexicographically least universal cycle for the set of length n binary strings whose weight are in the range $c, c+1, \ldots, n$.

The Gluing lemma can also be applied to construct universal cycles for other combinatorial objects including passwords and labeled graphs.

This is a joint work with Joe Sawada and Aaron Williams. (Received September 17, 2013)

1096-05-1609 **Jonathan A. Noel**, **Douglas B. West*** (west@math.uiuc.edu), **Hehui Wu** and **Xuding Zhu**. *Beyond Ohba's Conjecture: A bound on the choice number of k-chromatic graphs with n vertices.*

Let G be an n-vertex graph, and let $\mathrm{ch}(G)$ denote the choice number of G (also called "list chromatic number" or "choosability"). Noel, Reed, and Wu proved Ohba's conjecture that $\mathrm{ch}(G) = \chi(G)$ when $n \leq 2\chi(G) + 1$. We extend their result to a general upper bound for all graphs: $\mathrm{ch}(G) \leq \max\{\chi(G), \lceil (n + \chi(G) - 1)/3 \rceil\}$. Our bound is sharp for $n \leq 3\chi(G)$ using examples provided by Ohba, and it improves the best-known upper bound for $\mathrm{ch}(K_{4,\ldots,4})$. (Received September 16, 2013)

1096-05-1623 **Elizabeth Drellich*** (drellich@math.umass.edu), 167 South St Apt 8B, Northampton, MA 01060. *Peterson Varieties: a Uniform Giambelli's Formula.*

Subvarieties of the flag variety and generalizations of Springer fibers, Peterson varieties Pet_Δ lack many of the flag variety's nice properties. Nevertheless, Peterson varieties have a torus action which allows Schubert calculus style computations in the equivariant cohomology ring. Peterson Schubert classes form a basis of $H^*_{S^1}(Pet_\Delta)$ and generate the ring. Using excited Young diagrams we give a Giambelli's formula for Peterson varieties that is surprisingly simple and shockingly uniform across Lie type. Computations in Sage confirm that the result holds in the exceptional Lie types. The result suggests the existence of a uniform geometric proof of the formula. (Received September 16, 2013)

1096-05-1632 **Chris McCarthy*** (cmccarthy@bmcc.cuny.edu) and **Johannes Familton**. *Virtual Pascal's Triangles, Poisson's Equation and the Method of Images.*

We apply a technique from the physics of electrostatics, the method of images, which uses virtual charges to solve Poisson's Equation $\nabla\Phi = \rho/\epsilon_0$ for Φ (the scalar electric potential), to solve the classic Ballot Problem from combinatorial probability. Our proof involves path counting using virtual Pascal Triangles, analogs of virtual charges from electrostatics, and a uniqueness theorem which is analogous to the uniqueness theorem for Poisson's Equation. (Received September 16, 2013)

1096-05-1635 **Laszlo A. Szekely*** (szekely@math.sc.edu) and **Linyuan Lu** (lu@math.sc.edu).
Counting graphs with the Lovasz Local Lemma.

The Lovasz Local Lemma has been the tool to find the proverbial needle in the haystack. Recent advances allow the use of the Lovasz Local Lemma for permutation, graph and hypergraph enumeration asymptotically. One of the consequences is that—under mild conditions—most graphs with given degree sequence and girth have high chromatic number. (Received September 16, 2013)

1096-05-1640 **Matthew J Prudente*** (mjp209@lehigh.edu), 14 E. Packer Ave, Bethlehem, PA 18015.
Two-Player Variation on Graph Pebbling. Preliminary report.

Given a graph G with pebbles on the vertices, we define a *pebbling move* as removing two pebbles from a vertex and placing one pebble on its neighbor. The *pebbling number*, $\pi(G)$, of G is the least number of pebbles needed so that any arrangement of the $\pi(G)$ pebbles can reach any goal vertex through a sequence of pebbling moves. We define a new two-person pebbling game with players the *mover* and the *defender*. The mover and defender will alternate moves, with the stipulation that the defender cannot reverse the previous move. The mover wins if they can reach the root and the defender wins if the mover cannot. The value $\eta(G)$ is defined 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 for different classes of graphs such as paths, complete graphs and cycles. (Received September 16, 2013)

1096-05-1647 **Matthew Yancey*** (mpyancey1@gmail.com) and **Derrick Stolee**. *New bounds for the existence of many perfect matchings and large matchings.*

Turán theory studies how many edges are necessary to force a given fixed subgraph. Supersaturation counts the number of copies of a subgraph if the bound from Turán theory is slightly exceeded. We will consider a related problem when the given graph is a matching that covers all but a constant number of vertices.

This is joint work with Derrick Stolee. (Received September 16, 2013)

1096-05-1681 **Tyler Moss*** (jmoss11@math.lsu.edu). *Matroids that are extremal with respect to Bixby's Lemma.*

Bixby's Lemma is a well-known result in matroid theory that guarantees that any element in a 3-connected matroid can be removed in one of two ways while maintaining 3-connectivity. In this talk, we consider the 3-connected matroids that are extremal with respect to Bixby's Lemma in that each element can be removed in only one way to keep 3-connectivity. In particular, we look at how such matroids can be constructed and decomposed. (Received September 16, 2013)

1096-05-1685 **Joan P Hutchinson*** (hutchinson@macalester.edu), Department of Mathematics, Macalester College, Saint Paul, MN 55105. *A variation on Heawood-list-coloring for graphs on surfaces.*

Thomassen's celebrated planar 5-list-coloring theorem shows that if the vertices of a plane graph have 5-lists except that the vertices on one face have only 3-lists, then the graph can be list-colored. For a nonplanar surface $S(\epsilon)$ of Euler genus ϵ, let $H(\epsilon)$ be the Heawood number of $S(\epsilon)$, which is known to give the best coloring and list-coloring number for $S(\epsilon)$. We prove that for $\epsilon > 0$ and $\epsilon \neq 3$, every graph on $S(\epsilon)$ can be list-colored provided the vertices have $H(\epsilon)$-lists except that the vertices on one face have only $(H(\epsilon)-2)$-lists and provided the induced subgraph on vertices of that face does not contain $K_{H(\epsilon)-1}$. We compare this result with those of L. Postle and R. Thomas that hold for locally planar graphs on surfaces (that is, those embedded with all noncontractible cycles sufficiently long). (Received September 16, 2013)

1096-05-1700 **Catherine Erbes*** (catherine.erbes@ucdenver.edu), **Michael Ferrara**, **Ryan R. Martin** and **Paul Wenger**. *Degree-Sequence Stability of Graphs.*

A sequence of nonnegative integers is *graphic* if it is the degree sequence of a graph G; such a graph is called a *realization* of the sequence. The potential number of a graph H, denoted $\sigma(H, n)$, is the minimum even integer such that any graphic sequence of length n has a realization containing H as a subgraph. This is the degree-sequence analogue of the classical extremal number. The potential number has been determined asymptotically for general graphs H, and a family of extremal sequences that achieve this number is known. In this talk we give a stability result for the potential problem, similar to the stability results of Erdős and Simonovits for the Turán problem. A graph H has degree-sequence stability if every graphic sequence π with sum close to $\sigma(H, n)$ having no realization containing a copy of H can be transformed into an extremal sequence with $o(n)$ additions and subtractions. We discuss families of graphs that do and do not have degree-sequence stability. (Received September 16, 2013)

1096-05-1714 **Aziza F Jefferson*** (azjeffer@ufl.edu), University of Florida, Department of Mathematics, 358 Little Hall, Box 118105, Gainesville, FL 32611. *The enumeration of H&S pseudoknots.* Preliminary report.

RNA secondary structures are fundamental objects in mathematical biology. Many families of secondary structures have been introduced, including the *H&S* structures introduced by Haslinger and Stadler. We use the substitution decomposition and Lagrange inversion to enumerate the *H&S* family of structures. (Received September 16, 2013)

1096-05-1716 **Emlee W Nicholson*** (emlee.nicholson@millsaps.edu) and **Bing Wei** (bwei@olemiss.edu). *Degree conditions for weakly geodesic pancyclic graphs and their exceptions.* Preliminary report.

Let G be a graph on n vertices. Let $\sigma_2(G) = \min\{d_G(u) + d_G(v) : u, v \in V(G); uv \notin E(G)\}$ when G is not complete, otherwise set $\sigma_2(G) = \infty$. A graph G is said to be *weakly geodesic pancyclic* if for each pair of vertices $u, v \in V(G)$, every shortestu, v-path lies on a cycle of length k where k is an integer between the length of a shortest cycle containing the u, v-path and n. In this paper, we will show that if $\sigma_2(G) \geq n + 1$ then G is either weakly geodesic pancyclic or belongs to one of the exceptional classes of graphs, which are completely determined. Our results generalize some recent results of Chan et al (Discrete Applied Mathematics 155 (2007)). (Received September 16, 2013)

1096-05-1720 **Timothy R Morris*** (timothy.morris@ucdenver.edu). *Forbidden Subgraphs for Pancyclicity.*

A graph G of order n is *pancyclic* if G contains a cycle of length ℓ for each $3 \leq \ell \leq n$. Let $\mathcal{H}$ be a family of graphs. We say that a graph G is *$\mathcal{H}$-free* if, for each $H \in \mathcal{H}$, the graph G does not contain a copy of H as an induced subgraph. In 1984 Matthews and Sumner conjectured that every 4-connected $\{K_{1,3}\}$-free graph is hamiltonian. Brandt, Favaron, and Ryjáček showed in 2000 that for all $k \geq 2$ there exists a k-connected $\{K_{1,3}\}$-free graph that is not pancyclic. With this in mind, we characterize all graphs H such that all 4-connected $\{K_{1,3}, H\}$-free graphs are pancyclic. (Received September 16, 2013)

1096-05-1750 **Francis C. Motta*** (motta@math.colostate.edu), Department of Mathematics, 1874 Campus Delivery, Fort Collins, CO 80523-1874, and **Patrick D. Shipman** (shipman@math.colostate.edu) and **Bethany Springer** (springer@math.colostate.edu). *A Point of Tangency Between Combinatorics and Differential Geometry.*

Our investigation of the transitivity properties of infinite de Bruijn sequences built by extension, under the action of a shift map, led us to observe that edges of de Bruijn graphs whose labelled vertices are arranged in sequential order on a circle envelop epicycloids. (Received September 16, 2013)

1096-05-1753 **Allen J. Schwenk*** (schwenk@wmich.edu), Department of Mathematics, Western Michigan University, 1903 W Michigan Ave, Kalamazoo, MI 49008. *Independence sequences in a graph, constrained and unconstrained.* Preliminary report.

For a given graph G we consider two sequences. In the vertex independence sequence each ai denotes the number of ways to select a set of i independent vertices in G. The edge independence sequence bi is defined similarly. It has been known for some time that the edge sequence must be unimodal, whereas the vertex sequence is totally unconstrained. We examine the edge sequence to find additional constraints beyond the requirement of unimodality. (Received September 17, 2013)

1096-05-1805 **Stephen T. Hedetniemi*** (hedet@clemson.edu), School of Computing, Clemson University, Clemson, SC 29634, **Sandra M. Hedetniemi** (shedet@clemson.edu), School of Computing, Clemson University, Clemson, SC 29634, **Renu C. Laskar** (rclsk@clemson.edu), Department of Mathematical Sciences, Clemson University, Clemson, SC 29634, and **Gerd H. Fricke** (g.fricke@moreheadstate.edu), Department of Mathematics, Morehead State University, Morehead, KY 40351. *A Contribution to Irredundance and Distance-2 Domination in Graphs.* Preliminary report.

Let $G = (V, E)$ be a graph. The *open neighborhood* of a vertex $v \in V$ is the set $N(v) = \{u | uv \in V\}$ and the *closed neighborhood* of v is the set $N[v] = N(v) \cup \{v\}$. The *open neighborhood* of set S of vertices is the set $N(S) = \bigcup_{v \in S} N(v)$, while the *closed neighborhood* of a set S is the set $N[S] = \bigcup_{v \in S} N[v]$. A set $S \subset V$ *dominates* a set $T \subset V$ if $T \subseteq N[S]$. A set $S \subset V$ is a *dominating set* if $N[S] = V$; is a *minimal dominating set* if it is a dominating set, but no proper subset of S is also a dominating set; and is a *γ-set* if it is a dominating set of minimum cardinality. In this paper we consider the family $\mathcal{D}$ of all dominating sets of a graph G, the family $\mathcal{MD}$ of all minimal dominating sets of a graph G, and the family γ of all γ-sets of a graph G. The study of these three families of sets provides new characterizations of *distance*-2 *domination* and *irredundance* in graphs. (Received September 16, 2013)

1096-05-1807 **P. Mark Kayll*** (mark.kayll@umontana.edu). *Two chromatic conjectures: one for vertices, one for edges.*

Erdős, Faber and Lovász conjectured that a pairwise edge-disjoint union of n copies of the complete graph K_n has chromatic number n. This seeming parlour puzzle has eluded proof for more than four decades, despite attack by a few of the past century's more powerful combinatorial minds. Regarding edges, the 'list-colouring conjecture' asserts, loosely, that list-colouring is no more difficult than ordinary edge-colouring. Probably first proposed by Vizing, this notorious conjecture—also having garnered the attention of leading combinatorialists—has itself defied proof for almost forty years. Like any good mature conjecture, both of these ones have spawned interesting mathematics vainly threatening their resolution. This talk will consider some of the related partial results in concert with the conjectures themselves. (Received September 16, 2013)

1096-05-1817 **Chris Berg**, **Nantel Bergeron**, **Franco Saliola** and **Luis Serrano*** (serrano@lacim.ca), LaCIM, Universite du Quebec a Montreal, CP 8888, Succ. Centre-ville, Montreal, Quebec H3C 3P8, Canada, and **Mike Zabrocki**. *The immaculate basis of the non-commutative symmetric functions.*

We introduce a new basis of the non-commutative symmetric functions whose elements have Schur functions as their commutative images. Dually, we build a basis of the quasi-symmetric functions which expand positively in the fundamental quasi-symmetric functions and decompose Schur functions according to a signed combinatorial formula. These bases have many interesting properties similar to those of the Schur basis. (Received September 16, 2013)

1096-05-1840 **Bryan Tyler Ek*** (bte1759@rit.edu), 3608 29th Street, Chesapeake Beach, MD 20732. *Betweenness Centrality of Cycle Power Graphs.*

Betweenness centrality is a measure of the importance of a vertex to the optimal paths in a graph. Betweenness centrality of a vertex is defined as $bc(v) = \sum_{x,y} \frac{\sigma_{xy}(v)}{\sigma_{xy}}$ where σ_{xy} is the number of unique paths of shortest length between vertices x and y. $\sigma_{xy}(v)$ is the number of optimal paths that include the vertex v. In this paper, we examined betweenness centrality for vertices in C_n^m: a cycle power graph with vertices $v_1, \ldots, v_n$. v_i is connected to v_j if and only if $(i-j) \equiv \pm e \ mod \ n$ with $1 \leq e \leq m$. By the symmetry of C_n^m, every vertex will have the same betweenness centrality. Let $d = \lceil \frac{n-1}{2m} \rceil - 1$ and pick $r \equiv (1-n) \mod 2m$ such that $2m > r \geq 0$. Then $\forall v \in C_n^m$, $bc(v) = md(d+1) - rd$. (Received September 16, 2013)

1096-05-1855 **Glenn Appleby*** (gappleby@scu.edu) and **Tamsen Whitehead**. *An Elementary Construction of a Hive Associated to a Hermitian Matrix Pair, with Interpretations of Littelmann Path Operators.* Preliminary report.

Let M and N be two $n \times n$ Hermitian matrices. We provide an elementary construction of a hive $\{H(M,N)_{ijk}\}$ computed directly from this matrix pair, and prove that the direct sums of Hermitian matrix pairs corresponds to the convolution of their hives – that is, the overlay of their associated honeycombs. We then relate the deformations of honeycombs (and hives) determined by Littelmann's path operators to rotations of orthonormal bases of eigenvectors of M and N. (Received September 16, 2013)

1096-05-1869 **David P Sumner*** (sumner@math.sc.edu). *Forbidden Conjectures.*

Many theorems and conjectures in graph theory deal with the effects of forbidding particular subgraphs and most commonly these are trees. This talk will discuss some special conjectures of this kind focusing primarily on results dealing with chromatic number, Hamiltonian paths and cycles, perfect matchings, and domination number. (Received September 17, 2013)

1096-05-1883 **Kai Fong Ernest Chong*** (kc343@cornell.edu), Department of Mathematics, 310 Malott Hall, Cornell University, Ithaca, NY 14853. *Macaulay decomposability and the flag f-vectors of generalized colored complexes.*

A colored complex of type $\mathbf{a} = (a_1, \ldots, a_n)$ is a simplicial complex Δ together with an ordered partition $(V_1, \ldots, V_n)$ of its vertex set, such that every face F of Δ satisfies $|F \cap V_i| \leq a_i$. For each $\mathbf{b} = (b_1, \ldots, b_n)$, let $f_{\mathbf{b}}$ be the number of faces F of Δ such that $|F \cap V_i| = b_i$. The array of integers $\{f_{\mathbf{b}}\}_{\mathbf{b} \leq \mathbf{a}}$ is called the fine f-vector of Δ, and it is a refinement of the f-vector of Δ.

In this talk, we introduce the notion of **a**-Macaulay decomposability for simplicial complexes. An **a**-Macaulay decomposable simplicial complex is vertex-decomposable, and every pure color-shifted **a**-balanced complex is **a**-Macaulay decomposable. This allows a geometric interpretation of 'decomposing' such complexes into pieces we can better understand, and we discuss its relation to numerical characterizations of the fine f-vectors of colored complexes of arbitrary type, and the flag f-vectors of completely balanced Cohen-Macaulay complexes. (Received September 16, 2013)

1096-05-1901 **yasuyuki tsukamoto*** (tsukamoto@i.h.kyoto-u.ac.jp), Yoshida-nihonmatsu-cho Sakyo-ku, Kyoto, 606-8501, Japan. *an oriented matroid with a disconnected realization space.*

an oriented matroid is a combinatorial type of a (pseudo)hyperplane arrangement, and the hyperplane arrangement is called a realization of the oriented matroid. it is known that an oriented matroid can have a disconnected realization space, i.e. it can have two realizations which cannot be deformed continuously to each other without changing their oriented matroid. previously, i constructed an arrangement of 13 lines whose oriented matroid have a disconnected realization space, and the number of lines is less than the known examples with this property. i will explain how i found this example. (Received September 16, 2013)

1096-05-1905 **Elizabeth L. Wilmer***, elizabeth.wilmer@oberlin.edu, OH. *Truly random cables.*

Traditional cabled knitting can be very complex. Some recent knitting patterns use simple randomization to produce richly textured cabled fabric without memorization or charts. Most randomized cable patterns recommend occasional "cheating" to avoid aesthetic or functional problems. We analyze several models for random cables, ranging from coin flips through Markov chains on weighted tilings, and highlight the tradeoffs between mathematical aesthetics, physical aesthetics, and demands on the knitter. (Received September 16, 2013)

1096-05-1966 **Ryan K Therkelsen*** (rtherkelsen@bellarmine.edu). *A Multiset Generalization of t-Designs.* Preliminary report.

The connections between coding theory and design theory have been well studied. Codes over finite fields are typically associated with (traditional) designs, while a newer notion of multiset design – called k-coloured constant composition designs – has been shown to have analogous connections to linear codes over certain finite rings. In the traditional theory, t-designs are a major object of study, however for k-coloured constant composition designs a description analogous to t-designs has yet to be established. In this talk, I will propose such a description, outlining the similarities to traditional t-designs as well as some difficulties that arise when working in the multiset setting. (Received September 16, 2013)

1096-05-1990 **Steven Simon*** (ssimon2@wellesley.edu). *G-Ham Sandwich Theorems: Harmonic Analysis on Finite Measures.*

The Ham Sandwich Theorem asserts that any n finite measures on $\mathbb{R}^n$ can be bisected by a single hyperplane. Giving this theorem a $\mathbb{Z}_2$-interpretation, we provide group-theoretic generalizations - G-Ham Sandwich Theorems - of this most famous result of equipartition theory, showing in a general sense how finite measures on Euclidian space can be "G-balanced" with respect to finite linear representations of a Lie Group G. For abelian groups, this balancing of measures has a harmonic analysis interpretation in terms of the vanishing of Fourier coefficients, from which measure partitions by convex fundamental domains (e.g., in the case G is a finite abelian group, by the regions determined by multiple regular p-fans for varying $p \geq 2$) follow as special cases. (Received September 17, 2013)

1096-05-1991 **Susanna Fishel*** (sfishel1@asu.edu), School of Math. and Stats. Sciences, Arizona State University, Tempe, AZ 85287, and **Matjaz Konvalinka** (matjaz.konvalinka@fmf.uni-lj.si), Department of Mathematics, University of Ljubljana, Jadranska 21, Ljubljana, Slovenia. *Enumeration of strong, standard, starred tableaux.*

Schur functions are a basis for the ring of symmetric functions, one with many important algebraic and combinatorial properties. k-Schur functions are a basis for a certain subring of that ring and are turning out to be just as interesting. Many results involving Schur functions have analogues involving k-Schur functions. Standard strong marked tableaux play a role for k-Schur functions similar to the role standard Young tableaux play for Schur functions. I will discuss results and conjectures toward an analogue of the hook length formula. This is joint work with Matjaž Konvalinka. (Received September 17, 2013)

1096-05-2001 **Ryan W Matzke*** (matzry01@gettysburg.edu). *Subtraction Adds Nothing: The Minimum Sized h-fold Span of m-sized Subsets of Cyclic Groups.* Preliminary report.

Let G be a finite cyclic group written with additive notation. For a positive integer h and a nonempty subset A of G, we let hA and $h_{\pm}A$ denote the h-fold unrestricted sumset of A and the h-fold unrestricted span of A, respectively; that is, hA is the collection of sums of h not-necessarily-distinct elements of A, and $h_{\pm}A$ consists of all signed sums of h not-necessarily-distinct elements, meaning you can add or subtract each element rather than only add. For a positive $m \leq |G|$, we let

$$\rho(\mathbb{Z}_n, m, h) = \min\{|hA| : A \subseteq G, |A| = m\}$$

and

$$\rho_{\pm}(\mathbb{Z}_n, m, h) = \min\{|h_{\pm}A| : A \subseteq G, |A| = m\}.$$

While one might intuitively think that $\rho(\mathbb{Z}_n, m, h)$ would tend to be smaller, we find that the two are always equal. (Received September 17, 2013)

1096-05-2032 **Michal Kotrbcik*** (qkotrbc@fi.muni.cz), Faculty of Informatics, Masaryk University, Botanicka 68a, 60200 Brno, Czech Rep. *Semicages and extremal problems for maximum genus.*

Maximum genus of a graph G is the largest integer g such that G has a cellular embedding into the orientable surface of genus g. It is widely known that the maximum genus of a given graph can be calculated through a min-max formula given by theorems of Xuong and Nebeský. With the aid of this characterisation, a significant effort was invested into determining the lowest possible maximum genus and finding the extremal graphs in particular graph classes, such as graphs with a given connectivity or girth. In this talk we present a new method for attacking this type of problems by relating the maximum genus with the existence of induced subgraphs with odd cycle rank separated from the rest of the graph by at most 3 edges. The bounds on the maximum genus are then obtained by counting the maximum number of such induced subgraphs in graphs with a fixed size which belongs to the class in consideration. We illustrate the technique by calculating the maximum genus of regular graphs, as well giving very simple proofs of several classical results in the area. One of the main advantages of our approach is that in many cases, the obtained bounds are tight. (Received September 17, 2013)

1096-05-2037 **Heather D Jordon*** (hdj@ams.org) and **Joy Morris**. *Cyclic m-Cycle Systems of Complete Graphs minus a 1-factor.* Preliminary report.

In this talk, we will provide necessary and sufficient conditions for the existence of a cyclic m-cycle system of $K_n - I$ when m and n are even and $m \mid n$. (Received September 17, 2013)

1096-05-2058 **Nicholas A Scoville*** (nscoville@ursinus.edu), 610 E. Main Street, Dept. of Math and CS, Collegeville, PA 19426, and **Seth Aaronson**, **Mitch Smith**, **Marie Meyer** and **Laura Stibich**. *Graph isomorphisms via discrete Morse theory.*

A discrete Morse function f on a graph G induces a sequence of subgraphs of G. Two discrete Morse functions f and g on a graph G are said to be graph equivalent if f and g produce isomorphic subgraphs at each stage of the sequence. In this talk, we count the number of equivalence classes on star graphs S_n and deduce an upper bound for the number of equivalence classes for a certain collection of graphs. (Received September 17, 2013)

1096-05-2060 **Jim Haglund*** (jhaglund@math.upenn.edu) and **Adriano Garsia** (garsia@math.ucsd.edu). *A Constant Term Expression for the Character of Diagonal Harmonics.* Preliminary report.

In this talk we discuss a recent result of the speaker and Garsia, which expresses the character of the space of diagonal harmonics as the constant term in a multivariate Laurent series. Connections with the theory of Macdonald polynomial and plethystic symmetric function identities are highlighted. (Received September 17, 2013)

1096-05-2074 **Michael Severino*** (michael.severino@umontana.edu). *A construction of uniquely n-colorable digraphs without short cycles.*

A natural digraph analogue of the graph-theoretic concept of an 'independent set' is that of an 'acyclic set', namely a set of vertices not spanning a directed cycle. Hence a digraph analogue of a graph coloring is a decomposition of the vertex set into acyclic sets. In the spirit of a famous theorem of P. Erdős [Graph theory and probability, Canad. J. Math., **11**:34–38, (1959)], it was shown probabilistically in [D. Bokal et al., The circular chromatic number of a digraph, J. Graph Theory, **46**(3): 227–240, 2004] that there exist digraphs with arbitrarily large girth and chromatic number. Here I give a construction of such digraphs as well as define a product of these highly chromatic digraphs with the directed analogue of the complete graph. This product gives a construction of uniquely n-colorable digraphs without short cycles. (Received September 17, 2013)

1096-05-2093 **Thomas Ansill**, **Bonnie Jacob** (bcjntm@rit.edu), **Jaime Penzellna** and **Daniel Saavedra*** (dxs6040@rit.edu). *Failed zero forcing and failed skew zero forcing on graphs.*

Given a graph G, the zero forcing number of G, Z(G), is the smallest cardinality of any set S of vertices on which repeated applications of the color change rule results in all vertices joining S. The color change rule is: if a vertex v is in S, and exactly one neighbor u of v is not in S, then u joins S in the next iteration. The skew zero forcing number of G, Z^{-}(G), is the same, but with a slightly modified color change rule, namely that the vertex v itself need not be in S.

We have introduced two new graph parameters: the failed zero forcing number, F(G), and the failed skew zero forcing number F^{-}(G). The failed zero forcing number of G, F(G), is the maximum cardinality of any set of vertices on which repeated applications of the color change rule will never result in all vertices joining the set. F^{-}(G) is defined similarly, but under the modified color change rule.

In this talk, we establish bounds on F(G) and F^{-}(G). We determine formulas for the failed zero forcing numbers and failed skew zero forcing numbers of several families of graphs, and compare properties of these two parameters. (Received September 17, 2013)

1096-05-2106 **Emily A. Marshall*** (emily.a.marshall@vanderbilt.edu) and **David R. Wood**. *Circumference and Pathwidth of Highly Connected Graphs.*

Etienne Birmele proved that every graph with circumference t has treewidth at most $t-1$. Under the additional assumption of 2-connectivity, results of J. Nešetřil and P. Ossona de Mendez show that such graphs have bounded pathwidth, which is a qualitatively stronger conclusion. We make a factor-2 improvement to their bound. Birmele's theorem was extended by Birmele, Bondy and Reed who showed that every graph without k disjoint cycles of length at least t has bounded treewidth (as a function of k and t). Under the additional assumption of $(k+1)$-connectivity, we prove that such graphs have bounded pathwidth. Moreover, examples show that $(k+1)$-connectivity is required to reach this conclusion. These results suggest the following general question: for which values of k and H does every k-connected H-minor-free graph have bounded pathwidth? We discuss this question and provide a few observations. (Received September 17, 2013)

1096-05-2111 **Ronald J. Gould*** (rg@mathcs.emory.edu), Atlanta, GA 30322. *More about chorded cycles.*

The study of chorded cycles has seen a recent increase in activity in the past few years. I will review some of this work as well as consider several new results related to classic cycle results. This will include conditions sufficient to imply k independent edges being the chords of k disjoint cycles and k vertices being placed on k disjoint chorded cycles. (Received September 17, 2013)

1096-05-2113 **David C Vella*** (dvella@skidmore.edu), Dept. Mathematics and Computer Science, Skidmore College, 815 N. Broadway, Saratoga Springs, NY 12866. *Catalan Numbers, Fine Numbers, and Partitions.* Preliminary report.

In this talk we explore a new recursion formula for the Catalan numbers. Although the recursion was discovered via manipulating the generating function of the Catalan numbers, we can give a combinatorial proof using generalized Dyck words. A slight modification results in a new expression for Fine numbers in terms of Catalan numbers. Both the Catalan recursion formula and the formula for Fine numbers are expressed as sums over integer partitions. (Received September 17, 2013)

1096-05-2124 **Anders S. Buch*** (asbuch@math.rutgers.edu). *Equivariant cohomology of two-step flag varieties.*

I will present a proof of my conjectured puzzle formula for the equivariant Schubert structure constants of two-step flag varieties. This formula generalizes Knutson and Tao's puzzle rule for the equivariant cohomology of Grassmannians, as well as the cohomological puzzle rule for two-step flag varieties that was conjectured by Knutson in 1999 and proved recently by Kresch, Purbhoo, and the speaker. My results together with the equivariant version of the 'quantum equals classical' theorem implies a Littlewood-Richardson rule for the equivariant quantum cohomology of Grassmannians. (Received September 17, 2013)

1096-05-2144 **Roman Nedela***, Institue of Mathematics, Slovak Academy of Science, Dumbierska 1, 97549, Banska Bystrica, Slovak Rep. *Graph coverings and harmonic functions on graphs.* Preliminary report.

The theory of graph covers is central in topological graph theory. Its development is closely related to the solution of the Heawood map colour problem Ringel and Youngs and to the investigation of highly symmetrical graphs, where it served as a universal construction method, see works of Biggs and others. Later, it found applications in other areas of graph theory including the degree-diameter problem, flows on graphs, spectral theory and others.

In the present talk we first resume the state of art of the theory and applications. Then we shall discuss a generalization of graph coverings to harmonic functions defined on graphs – a new recently opened area of research connecting graph theory to classical fields of continuous mathematics dealing with the theory of manifolds, Riemann surfaces and elliptic curves. (Received September 17, 2013)

1096-05-2158 **Olivia M. Carducci*** (ocarducci@esu.edu). *The Stable Matchings Exist, But Why?*

There are many variants of the classic stable marriage problem. In applications matching positions and job applicants, an important variant is to allow couples to express preferences over pairs of positions. It is known that there may not be a stable matching in this context and that finding a stable matching or showing that none exist is NP-complete. However, in practice, matches like the National Resident Matching Program (NRMP) are successful in finding stable matchings year-after-year. The question is why? What is it about the structure of the preferences in the NRMP that cause there to be a stable matching? This talk will summarize the known results in this area and present directions for further work. (Received September 17, 2013)

1096-05-2189 **Liviu Mare** and **Leonardo C Mihalcea*** (lmihalce@math.vt.edu), 460 McBryde, Virginia Tech, Blacksburg, VA 24060. *A quantum Chevalley rule for affine flag manifolds.* Preliminary report.

The notion of a "curve neighborhood" of a Schubert variety in a finite flag manifold, studied recently by A. Buch and the speaker, has a natural generalization to affine flag manifolds X. In analogy to the finite case, one can define an "affine quantum Chevalley" rule, i.e a multiplication of a Schubert class in the cohomology ring of X by a Schubert class of (complex) degree 1. This product deforms the usual product of Schubert classes in the cohomology ring of X, it coincides with one conjectured earlier in type A by M. Guest and T. Otofuji, but it is only associative modulo a product of (affine) quantum parameters. However, we can still define a ring which deforms the quantum cohomology ring of the finite dimensional flag manifold, and, analogous to a result of B. Kim, it has a presentation with the ideal of relations generated by the conserved quantities in the periodic Toda lattice. This is joint work with Liviu Mare. (Received September 17, 2013)

1096-05-2191 **Levi A Altringer*** (laltrin@linfield.edu), 959 NW 11th St., McMinnville, OR 97128. *Competitive Tiling.*

Competitive tiling consists of two players, a tile set, a region, and a non-negative integer d. Alice and Bob, our two players, alternate placing tiles on the untiled squares of the region. They play until no more tiles can be placed. Alice wins if at most d squares are untiled at the end of the game, and Bob wins if more than d squares are untiled. For given regions and tile sets we are interested in the smallest value of d such that Alice has a winning strategy. We call this the game tiling number. In this talk we focus on finding the game tiling number for the game played with dominoes on $2 \times n$ rectangles, modified $2 \times n$ rectangles, and rectangular annular regions. (Received September 17, 2013)

1096-05-2196 **Daisuke Suyama*** (dsuyama@math.sci.hokudai.ac.jp), Department of Mathematics, Hokkaido University, Kita-10, Nishi-8, Kita-ku, Sapporo, Hokkaido 060-0810, Japan. *Basis construction of extended Shi and Catalan arrangements of the type A_2.* Preliminary report.

Let Φ be a finite crystallographic irreducible root system. The Weyl arrangement of Φ is the set of all linear hyperplanes orthogonal to positive root in Φ. Extended Shi arrangements and extended Catalan arrangements are obtained by adding to the Weyl arrangement several parallel translations of hyperplanes in the Weyl arrangement. In this talk, we will construct bases for the derivation modules of extended Shi and Catalan arrangements of the type A_2. This is a joint work with Takuro Abe. (Received September 17, 2013)

1096-05-2201 **Will Grilliette*** (wgrilliette@uttyler.edu), RBN 4005, University of Texas at Tyler, 3900 University Blvd, Tyler, TX 75799. *Blow-Ups and Injectivity of Quivers.*

This talk is based on joint work with Drs. Deborah and Tyler Seacrest. In this talk, I connect the idea of a "blow-up" of a quiver with that of injectivity, showing that for a class of monic maps Φ, a quiver is Φ-injective if and only if all blow-ups of it are as well. This relationship is then used to characterize all quivers that are injective with respect to the natural embedding of P_n into C_n. (Received September 17, 2013)

1096-05-2205 **Garth Isaak*** (gisaak@lehigh.edu). *Degree lists for multiforests and near multiforests.*
We characterize which lists can be realized as the degrees for multigraphs in several different families with underlying treelike structure. These provide nice examples for possible extended exercises in graph theory classes. Examples include multigraphs with underlying graph a tree or forest as well as observing that all multigraphs can be realized with at most one underlying cycle. We also characterize degree lists for trees, forests and graphs with at most one cycle when at most 2 parallel edges are allowed. (Received September 17, 2013)

1096-05-2216 **Gregory S. Warrington*** (gswarrin@uvm.edu), Department of Mathematics & Statistics, 16 Colchester Ave., Burlington, VT 05401. *Crosshatch permutations.*
We present some new results on crosshatch permutations and their relationship to type-A Kazhdan-Lusztig polynomials. (Received September 17, 2013)

1096-05-2217 **William R. Pulleyblank*** (william.pulleyblank@usma.edu), United States Military Academy, Department of Mathematical Sciences, West Point, NY 10996. *Optimal linear arrangements and graceful labelings of graphs.*
A graceful labeling of a tree with n vertices is a labeling of its vertices with $\{1, 2, \ldots, n\}$ such that each vertex gets a distinct label, and such that, for each edge, the absolute difference between the labels on its endpoints is distinct. Forty-six years ago it was conjectured that every tree has a graceful labeling. This conjecture, called the Ringel-Kotzig conjecture, is still unresolved.

The Optimal Linear Arrangement problem is closely related. It again requires labeling the vertices of an n vertex graph with $\{1, 2, \ldots, n\}$ and then defining the label of each edge to be the absolute difference between the labels on its endpoints. The objective of this problem is to find such a vertex labeling for which the sum of the derived edge labels is minimum. Yossi Shiloach (1979) gave a polynomially bounded algorithm for solving this problem in trees, but which has not yet been successfully generalized to series-parallel graphs.

We discuss mixed integer programming formulations of these problems which seem to provide effective means of solving these problems for "moderately" sized graphs (dozens but not hundreds of vertices). This also leads to a strengthened version of the Ringel-Kotzig conjecture which, to our knowledge, is not resolved. (Received September 17, 2013)

1096-05-2228 **Vijay Jung Kunwar*** (vkunwar@math.fsu.edu) and **Mark van Hoeij** (hoeij@math.fsu.edu). *Hypergeometric Solutions of Second Order Linear Differential Equations with Five Singularities.*
Differential equations with Hypergeometric solutions are very common in Combinatorics and Physics. Given a second order linear differential operator L with rational function coefficients, we want to find (if it exists) a ${}_2F_1$-type solution of L. More specifically, we want to find a non zero expression:

$$y = \exp(\int r\,dx)\Big(r_0 S(f) + r_1 S(f)'\Big) \tag{1}$$

such that $L(y) = 0$, where $S(f) = {}_2F_1(a, b; c \,|\, f)$, and f, r, r_0, r_1 are rational functions.
Current projects in this area include (i) finding ${}_2F_1$-type solutions of second order differential operators with n regular singularities, and (ii) finding ${}_2F_1$-type solutions with specific degree of f.
If the generating function of an integer sequence is convergent and holonomic, then we observed that it satisfies a differential equation with logarithmic singularities which has ${}_2F_1$-type solution. This gives us a way to prove that the sequence is an integer sequence. In this talk, I will present an algorithm to find a ${}_2F_1$-type solution of a second order linear differential operator with five regular singularities where at least one singularity is logarithmic. (Received September 17, 2013)

1096-05-2236 **Daniel R Droz*** (droz@math.psu.edu). *Polynomial-Generated Orthogonal Latin Squares and Hypercubes.*
The search for sets of mutually orthogonal latin squares (MOLS) at non-prime powers has proven a confounding question. When we consider latin squares of order n (that is, $n \times n$ arrays on n symbols where no symbol is repeated in a row or column) which have n a prime power, it is simple to construct examples via polynomials over finite fields. And if we require sets of such squares to be mutually orthogonal (that is, when superimposed each pair of symbols occurs exactly once), we can find sets of such polynomials that attain the theoretical maximum: where $N(n)$ is the maximum size of such a set of squares of order n, $N(n) \leq n - 1$. But when n is not a prime power, there is no finite field of order n and things become more difficult. Although values for $N(n)$ are not determined for non-prime powers (except $N(6) = 1$) in this talk we explore what happens when we require the squares to be generated by polynomials over finite rings. In this case we can determine a maximum size of set of

MOLS for all n. We also extend our reach to higher-dimensional arrays, and to frequency squares. (Received September 17, 2013)

1096-05-2256 **Alessandra Graf*** (ag668@nau.edu). *Recent Developments Concerning Two Conjectures by Frucht.*

A graceful labeling of a graph G with q edges is an injective assignment of labels from $\{0, 1, \ldots, q\}$ to the vertices of G such that when each edge is assigned the absolute value of the difference of the vertex labels it connects, the resulting edge labels are distinct. In a 1978 paper, Roberto Frucht made some intriguing conjectures while investigating graceful labelings of coronas $C_n \odot K_1$. We will summarize results from recent papers that address these conjectures, and discuss some newer developments. (Received September 17, 2013)

1096-05-2262 **Jackie Kaminski*** (kaminski@juniata.edu), Jackie Kaminski, Juniata College, 1700 Moore St., Huntingdon, PA 16652. *Classification of Factored Gain-Graphic Hyperplane Arrangements.*

The property of inductive factorizability of a hyperplane arrangement, which is one way an arrangement can be shown to be free. Inductive factorizability is a matroid property, as such it generalizes to the frame matroid of a gain graph over an arbitrary group. A weaker property is factorizability. I have classified all factorizable gain graphic arrangements, which is the first step and biggest step towards a classification of inductively factorizable gain-graphic arrangements.

I will present the connection between gain graphs and the corresponding hyperplane arrangements, and the classification (in graph theoretic terms) of factored gain-graphic arrangements. (Received September 17, 2013)

1096-05-2270 **Marston D E Conder*** (m.conder@auckland.ac.nz), University of Auckland, New Zealand, and **Ricardo Grande**, University of the Basque Country, Spain. *Embeddings of circulants.*

Circulants are Cayley graphs for cyclic groups, and admit dihedral symmetries. This talk is a brief account of some work on the genus spectrum of embeddings of circulants (on orientable surfaces), carried out when Ricardo visited Auckland as a 'summer' research student with Marston. The first part concerns the *maximum genus*. It can easily be shown that every connected circulant is *upper-embeddable*, having an embedding with just one or two faces. The second (and more challenging) part concerns the *minimum genus*. In the course of doing this work, several counter-examples were found to a claimed theorem by Costa, Strapasson, Alves and Carlos (2010) on toroidal embeddings (genus 1), and then all connected circulants having minimum genus 1 or 2 were completely determined. This involved a combination of mathematics and computer experimentation, some of which will be described, with illustrations. (Received September 17, 2013)

1096-05-2276 **Shaofei Du**, **Roman Nedela** and **Martin Skoviera*** (skoviera@dcs.fmph.uniba.sk), Department of Computer Science, Comenius University, 842 48 Bratislava, Slovak Rep. *Bounding the order of a regular map with nilpotent automorphism group.*

Several interesting classes of graph embeddings giver rise to regular maps with nilpotent automorphism group. Among them are, for example, regular embeddings of complete bipartite graphs $K_{n,n}$ or n-cubes Q_n where n is a power of 2. We investigate regular maps with nilpotent automorphism group in detail and show that every orientably regular map whose automorphism group is nilpotent of class c has at most $2^{2^{c-1}}$ vertices. The bound can be reached only for $c \leq 3$, the largest of the extremal maps being a toroidal embedding of Q_4. For $c \geq 4$, the maximal order of a nilpotent orientably regular map of class c remains unknown. (Received September 17, 2013)

1096-05-2302 **Omar Ortiz*** (oortiz@uwo.ca). *A generalized GKM condition for p-compact flag varieties.*

In the late 1990's Goresky-Kottwitz-MacPherson found a characterization of the torus-equivariant cohomology of flag varieties that can be combinatorially described in terms of Bruhat graphs. In this talk I will show how GKM theory generalizes for the category of p-compact groups –the homotopy analogues of compact Lie groups. (Received September 17, 2013)

1096-05-2317 **Joshua N. Cooper***, 1523 Greene St., LeConte College, Columbia, SC 29210. *The Discrepancy of de Bruijn Sequences.*

We discuss aspects of the "discrepancy" of de Bruijn sequences, i.e., initial character sums over such sequences that measure the uniformity of distribution of its alphabet. The discrepancy of the lexicographically-least de Bruijn sequence is a natural question that has been studied in some detail, and it turns out to involve an unexpected family of Fibonacci-like sequences. Also, because of a surprising application of de Bruijn sequences to functional magnetic resonance imaging (fMRI), sequences which have specific frequency power spectra –

detectable via character sums – are of particular interest. We present these topics and several related questions. (Received September 17, 2013)

1096-05-2319 **Alexander K Woo*** (awoo@uidaho.edu) and **Alexander Yong**. *Kazhdan–Lusztig elements for adjoint Schuberts.* Preliminary report.

We calculate the Kazhdan–Lusztig elements (and hence polynomials) for permutations which are maximal coset representatives for the adjoint parabolic subgroup in types B and D. They turn out to almost be positive with respect to the basis given by principal lower ideals in Bruhat order and satisfy the 0-1 property. We use the original mu recursion aided by two bookkeeping devices, the root-theoretic Young diagrams of Searles and Yong and the aforementioned basis. Geometrically, our results describe the rationally smooth locus of associated Schubert varieties. (Received September 17, 2013)

1096-05-2322 **Chad B Birger*** (chad.birger@usiouxfalls.edu), 1101 W. 22nd St., Natural Science Area, Sioux Falls, SD 57105, and **Daniel Schaal**. *Zero-Sum Rado Numbers for some Linear Equations.*

In 1916, I. Schur proved the following theorem: For every integer t greater than or equal to 2, there exists a least integer n=S(t) such that for every coloring of the integers in the set $\{1, 2, ..., n\}$ with t colors there exists a monochromatic solution to $x + y = z$. R. Rado, who was a student of Schur, found necessary and sufficient conditions to determine if an arbitrary linear equation admits a monochromatic solution for every coloring of the natural numbers with a finite number of colors. Let L represent a linear equation or inequality and let t be an integer greater than or equal to 2. The least integer n, provided that it exists, such that for every coloring of the integers in the set $\{1, 2, ..., n\}$ with t colors there exists a monochromatic solution to L is called the t-color Rado number for L. If such an integer n does not exist, then the t-color Rado number for L is infinite. In this talk, we will consider a variation of 2-color Rado numbers using zero-sum solutions. Given a 2-coloring, $\Delta : \{1, 2, ..., n\} \to \{0, 1\}$, a zero-sum solution for an equation in m variables is the m-tuple, $(x_1, x_2, ..., x_m)$ that forms a solution for an equation and $\Delta(x_1) + \Delta(x_2) + ... + \Delta(x_m) \equiv 0 \bmod 2$. (Received September 17, 2013)

1096-05-2349 **James M. Carraher**, **Stephen G. Hartke**, **David Galvin**, **A. J. Radcliffe** and **Derrick Stolee*** (dstolee@iastate.edu). *On independent sets in Cayley graphs over* $\mathbb{Z}$. Preliminary report.

A circulant graph is a Cayley graph over $\mathbb{Z}_n$. Determining the independence number or clique number of a circulant graph is a difficult problem. Motivated by recent work on uniquely K_r-saturated graphs, we investigate the density of independent sets in finitely-generated Cayley graphs over the integers. We use a search for periodic sets to provide lower bounds and use discharging arguments to find upper bounds. We are able to determine the exact density for many generator sets, but also state several conjectures. (Received September 17, 2013)

1096-05-2361 **Casey Kenneth Moffatt*** (caseymoffatt@msn.com), 9143 W 75th CR, Arvada, CO 80005. *On The Potential Function For Degree Sequences Of Multi-Graphs.* Preliminary report.

A sequence of nonnegative integers $\pi = (d_1, d_2, ..., d_n)$ is *graphic* if there is a (simple) graph G with degree sequence π. In this case, G is said to *realize* or be a *realization of* π. Given a graph H, a graphic sequence π is *potentially* H*-graphic* if there is some realization of π that contains H as a subgraph. In 1991, Erdős, Jacobson and Lehel posed the following, which can be viewed as a degree sequence analogue to the classical Turán problem, "Determine the minimum integer $\sigma(H, n)$ such that every n-term graphic sequence with sum at least $\sigma(H, n)$ is potentially H-graphic." The exact value of $\sigma(H, n)$ has been determined for a number of specific classes of graphs (including cliques, cycles, complete bigraphs and others). In this talk, we will discuss the extension of this *potential function*, $\sigma(H, n)$, where H is a (loopless) multi-graph. (Received September 17, 2013)

1096-05-2366 **André Kündgen*** (akundgen@csusm.edu), Department of Mathematics, California State University San Marcos, San Marcos, CA 92096, and **Janina Patno**. *Expected Reliability of Communication protocols.*

We consider the problem of sending a message between a sender s and a receiver r through an asynchronous, unreliable network by specifying in a protocol what each vertex is supposed to do if it receives the message from one of its neighbors. A protocol for routing a message in such a network is *finite* if it never generates an infinite number of copies of the message. The *expected reliability* of a given finite protocol is the probability that a message sent from s reaches r when the edges of the network fail independently with probability p.

We discuss, for given networks, the properties of finite protocols with maximum expected reliability in the case when p is close to 0 or 1, and we describe networks for which no one protocol is optimal for all values of p. In general finding an optimal protocol for a given network and fixed probability is challenging and many open problems remain. (Received September 17, 2013)

1096-05-2378 **Dae Hyun Kim**, **Alex Mun** and **Mohamed Omar*** (omar@g.hmc.edu), 301 Platt Boulevard, Claremont, CA 91711. *Chromatic Bounds for Orbital Chromatic Roots.* Preliminary report.

Given a group G of automorphisms of a graph Γ, the orbital chromatic polynomial $OP_{\Gamma,G}(x)$ is the polynomial whose value at a positive integer k is the number of orbits of G on proper k-colorings of Γ. In their seminal paper, Cameron et. al. explore the roots of orbital chromatic polynomials, and in particular prove that orbital chromatic roots are dense in $\mathbb{R}$, extending Thomassen's famous result that chromatic roots are dense in $[\frac{32}{27}, \infty)$. Cameron et al further conjectured that the real roots of the orbital chromatic polynomial of a graph are bounded above by the largest real root of its chromatic polynomial. We resolve this conjecture in the negative, and provide a process for generating families of counterexamples. (Received September 17, 2013)

1096-05-2392 **Geoffrey Exoo*** (ge@cs.indstate.edu), Department of Mathematics and Computer Scienc, Indiana State University, Terre Haute, IN 47809. *On the Conjecture of Erdős and Gyárfás.* Preliminary report.

The Erdős and Gyárfás Conjecture states that any graph with minimum degree three contains a cycle whose length is a power of two. Over the years the speaker has collected a lot of data related to this conjecture. Perhaps in the hands of others, this data could lead to progress on the problem. So partial results on the problem are summarized. Such results include solutions for sequences of integers that are slightly less dense, and slightly more dense, than the powers of two. It appears that the powers of two are precisely the right sequence to make the problem difficult. (Received September 17, 2013)

1096-05-2394 **Arun Ram**, **Martha Yip*** (myip@math.upenn.edu) and **Meesue Yoo**. *Macdonald polynomials with shifted parameters.* Preliminary report.

The classical Weyl character formula for the type A root system states that the Schur function $s_\lambda = \frac{a_{\lambda+\rho}}{a_\rho}$, where $a_{\lambda+\rho} = \det[x_i^{\lambda_j+n-j}]$ (and a_ρ is the Vandermonde determinant). More generally, the Macdonald polynomial $P_\lambda(q,t)$ is a symmetric function which specializes to s_λ at $q = t = 0$. In this case, the qt-analogue of the Weyl character formula expresses the Macdonald polynomial with shifted parameters as $P_\lambda(q,qt) = \frac{A_{\lambda+\rho}(q,t)}{A_\rho(q,t)}$. Inspired by this, we use the alcove walk model for computing Macdonald polynomials to obtain a combinatorial formula for expressing the shifted $P_\lambda(q,qt)$ as a linear combination of $P_\nu(q,t)$. This is joint work with A. Ram and M. Yoo. (Received September 17, 2013)

1096-05-2399 **Elizabeth Beazley**, **Anna Bertiger** and **Kaisa Taipale*** (taipale@math.umn.edu). *An equivariant rim-hook rule for quantum cohomology of Grassmannians.* Preliminary report.

In 1999, Bertram, Ciocan-Fontanine and Fulton related quantum multiplication of Schur polynomials to the classical product via rim-hook removal. This is called the "rim-hook rule." Since the Littlewood-Richardson rule is easily accessible, this means that products in $QH^*(Gr(k,n))$ are also similarly accessible. We provide an equivariant version of this rim-hook rule, explicitly relating the rings $QH^*_T(Gr(k,n))$ and $H^*_T(Gr(k,2n-1))$. This allows computations in $QH^*_T(Gr(k,n))$ using combinatorial devices such as Knutson and Tao's puzzles for $H^*_T(Gr(k,n))$. Interestingly, this rule requires a specialization of torus weights that is tantalizingly similar to phenomena in affine Schubert calculus, which is related to Gromov-Witten theory by Peterson's theorem. (Received September 17, 2013)

1096-05-2408 **Jennifer Morse*** (morsej@math.drexel.edu), 3141 Chestnut Street, Philadelphia, PA 19104. *Flag Gromov-Witten invariants and Macdonald polynomials.*

We show how to identify the set of 3-point Gromov-Witten invariants for flag manifolds and the WZW fusion rules as coefficients in a product of k-Schur functions. Using symmetric function combinatorics, we describe a defining set of invariants. Time permitting, we show how this approach gives a t-parameter family of representatives for the Schubert classes of cohomology of the affine Grassmannian that is connected to Macdonald symmetric functions. (Received September 17, 2013)

1096-05-2429 **Katherine F. Benson*** (katie.benson@westminster-mo.edu). *On Radio Labeling of Some Caterpillar Graphs.* Preliminary report.

A radio labeling of a simple connected graph G with diameter D is a function $f : V(G) \to \mathbb{Z}^+$ such that for every two distinct vertices u and v of G, the radio condition, $d(u,v) + |f(u) - f(v)| \geq D + 1$ is satisfied. The radio number of a graph G is the smallest integer m for which there exists a radio labeling f with $f(v) \leq m$ for all $v \in V(G)$. A general lower bound for the radio number of trees, and thus caterpillar graphs, has already been established. In this talk, we discuss when an upper bound to match this lower bound is not possible due to the structure of some caterpillar graphs. For other particular caterpillar graphs whose radio number can be determined, we discuss strategies on the order to label the vertices to achieve this optimal labeling. (Received September 17, 2013)

1096-05-2437 **Craig M Timmons*** (ctimmons@ucsd.edu) and **Michael Tait** (mtait@ucsd.edu). *Sidon sets and graphs without 4-cycles.*

Determining the maximum number of edges in an n-vertex graph that does not contain a 4-cycle is a problem with a rich history in extremal graph theory. Using Sidon sets, for each odd prime power q we construct a graph that does not contain a 4-cycle and has $q^2 - q - 2$ vertices and $\frac{1}{2}q^3 - q^2 - O(q^{3/4})$ edges. This disproves a conjecture of Abreu, Balbuena, and Labbate. This is joint work with M. Tait of University of California, San Diego. (Received September 17, 2013)

1096-05-2456 **Jobby Jacob*** (jxjsma@rit.edu) and **Christopher Wood**. *On $L(2,1)$ labeling of trees.*

An $L(2,1)$ coloring of a graph G is an integer labeling of the vertices where adjacent vertices differ in label by at least two, and vertices that are at distance two from each other differ in label by at least one. That is, an $L(2,1)$ *coloring* of G is a vertex labelling $f : V(G) \longrightarrow \{0\} \cup \mathbb{Z}^+$ such that

(1) $|f(u) - f(v)| \geq 2$ for all $uv \in E(G)$,

(2) $|f(u) - f(v)| \geq 1$ if $d(u,v) = 2$.

The *span of an* $L(2,1)$ *coloring* f on a graph G is the $\max f(u)$ for all $u \in V(G)$. The *span of a graph* G, denoted by $\lambda(G)$, is the minimum span of all $L(2,1)$ colorings on G. Griggs and Yeh showed that $\lambda(T) \in \{\Delta(T)+1, \Delta(T)+2\}$ for all trees T, however, no complete characterization of trees has been established.

We present a complete characterization of trees up to twenty vertices based on their $L(2,1)$-span. We will also show that finding a forbidden subtree characterization for higher order trees is extremely difficult. (Received September 17, 2013)

1096-05-2459 **Maryam Verdian-Rizi*** (mverdian@kaist.ac.kr) and **Martin Knor** (knor@math.sk). *Polyhedral nonagonal and decagonal fullerenes.* Preliminary report.

A fullerene is a cubic planar map with all faces of size 5 or 6. Hyperbolic analogues of fullerenes are defined as cubic maps of *face-type* $(6,k)$ for some $k \geq 7$ on an orientable surface of genus at least 2. For $k = 7$ and 8, Dutour Sikirić, Knor, Potočnik, Širáň and Škrekovski (2012) prove the existence of *polyhedral* cubic maps of face-type $(6,k)$ on surfaces of any genus $g \geq 2$ and with any number of hexagons α, except for the cases $k = 8$, $g = 2$ and $\alpha \leq 2$ where they show no such maps exist. For $k = 9$ and 10, we prove there exist a polyhedral map of face-type $(6,k)$ on the orientable surface of genus g with precisely α hexagons if and only if $\alpha \geq \alpha(k,g)$, where we give the exact value of $\alpha(k,g)$ for all $g \geq 2$. To achieve this, we give geometric constructions for the dual maps using Cayley maps as the basis. (Received September 17, 2013)

1096-05-2473 **Joel Brewster Lewis** (jblewis@umn.edu), Vincent Hall, Room 203b, 206 Church St SE, Minneapolis, MN 55455, and **Alejandro H. Morales*** (ahmorales@lacim.ca), 4130 Pavillon Président-Kennedy, Montréal, Québec H3C 3P8, Canada. *Combinatorics of diagrams of permutations.* Preliminary report.

In his study of the totally nonnegative Grassmannian, Postnikov introduced several combinatorial objects linked to a Grassmannian permutation $w = w_\lambda$. We study the connection between these objects when w is no longer required to be Grassmannian. These objects include regions in the inversion hyperplane arrangement of w, rook placements on the complement of the diagram of w, "Le"-fillings of the diagram of w, and permutations below w in the strong Bruhat order. We show that for any fixed permutation w the number of regions equals the number of rook placements and the number of certain fillings related to "Le"-fillings. Then thanks to a conjecture of Postnikov, settled by Hultman-Linusson-Shareshian-Sjöstrand, we relate this number of regions/placements/fillings and one of its q-analogues to the number of permutations below w in the Bruhat order. This last relation settles part of a conjecture with Klein and Lewis. (Received September 17, 2013)

1096-05-2495 **Christina Graves** (cgraves@uttyler.edu), 3900 University Blvd., Tyler, TX 75799, **Jennifer McLoud-Mann*** (jmcloud@uw.edu), School of STEM, Box 358538, 18115 Campus Way NE, Bothell, WA 98011-8246, and **Kristen Stagg** (kstagg@uttyler.edu), 3900 University Blvd., Tyler, TX 75799. *Extending Patches to Fullerenes.* Preliminary report.

This presentation will discuss some fullerene patches that can be extended to pseudoconvex patches. In particular, we show that all fullerene disks with three or fewer pentagons can be extended to pseudoconvex patches and that all pseudoconvex patches can be extended to fullerenes. (Received September 17, 2013)

1096-05-2510 **Sara C. Billey*** (billey@math.washington.edu), Box 354350, Math dept, University of Washington, Seattle, WA 98105. *A Signed Little Map and Coxeter-Knuth Graphs.*

We propose an analog of the Little map for signed permutations. We show that this map respects the transition equations derived from Chevellay's formula on Schubert classes. We discuss many nice properties of the signed Little map which generalize recent work of Hamaker and Young in type A where they proved Lam's conjecture.

This talk is based on joint work with Zachary Hamacker, Austin Roberts and Benjamin Young. (Received September 17, 2013)

1096-05-2515 **Aaron Williams*** (haron@uvic.ca). *Greedy Constructions of de Bruijn Sequences and Gray Codes.*

In 1934, M. H. Martin gave the following greedy algorithm for constructing a binary de Bruijn sequence of order n: Start with 1^{n-1}, then repeatedly add the smallest bit (0 or 1) that does not create a duplicated substring of length n. For example, the result for $n = 4$ is 111 followed by 0000100110101111, which is the lexicographically smallest such de Bruijn sequence. The binary reflected Gray code has a similar construction: Start with 0^n, then repeatedly append a new string by complementing the rightmost possible bit of the previous string. For example, the result for $n = 3$ is $00\bar{0}, 0\bar{0}1, 01\bar{1}, \bar{0}10, 11\bar{0}, 1\bar{1}1, 10\bar{1}, 100$ with the complemented bits highlighted. Both algorithms generalize nicely from binary strings to k-ary strings.

Despite this strong foundation, greedy approaches to constructing generalizations of de Bruijn sequences and Gray codes have been largely overlooked. We reinterpret many classic results using simple greedy algorithms, and show that new results can also be obtained greedily. Preliminary results were presented at WADS 2013: A. Williams, *The Greedy Gray Code Algorithm*, LNCS 8037, 525–534, with an appendix appearing on the author's webpage: www.math.mcgill.ca/haron.
(Received September 17, 2013)

1096-05-2531 **Gwyneth R Whieldon*** (whieldon@hood.edu), 401 Rosemont Ave, Frederick, MD 21701, and **Alison G Schuetz**, 401 Rosemont Avenue, Frederick, MD 21701. *Combinatorial Interpretations of Coefficients of Iterated Polynomials.* Preliminary report.

Given a polynomial of the form $f(x,z) = g(z) + h(x)$, let $f^{(0)}(x) = 0$ and $f^{(n)}(x) = g(f^{(n-1)}) + h(x)$ for $n \geq 1$. Set $f^{\infty}(x) = \lim_{n\to\infty} f^{(n)}(x)$. We give conditions on $g(z)$ and $h(x)$ so that the power series $f^{\infty}(x) = \sum_{k=0}^{\infty} a_k x^k$ exists, and provide combinatorial interpretations of the coefficients a_k in terms of polygonal partitions. In particular, we provide examples of $g(z)$ and $h(x)$ such that the nonzero coefficients of $f^{\infty}(x)$ are the Catalan numbers $C_k = \frac{1}{k+1}\binom{2k}{k}$, the multivariate Fuss-Catalan numbers $C_k^{(d)} = \frac{1}{(d-1)k+1}\binom{dk}{k}$, and a "non-homogeneous" generalization of the Fuss-Catalan numbers. (Received September 17, 2013)

1096-05-2564 **Chinenye Ofodile*** (chinenye.ofodile@asurams.edu), Albany State University, Department of Mathematics & Computer Science, 504 College Drive., Albany, GA 31705. *The Enumeration of Dumont Permutation Containing Pattern 231 Exactly Once.*

In this work, Dumont permutations of the first kind with exactly one occurrence of pattern 231 is enumerated. Patterns are order-isomorphism classes of permutations (or, more generally, of strings over a totally ordered alphabet). Strings are order-isomorphic if and only if pairs of elements in the same positions satisfy the same pairwise comparisons. Dumont permutations are classes of permutations that satisfy certain restrictions based on parity of positions or values of elements. This work parallels the work of Burstein, Elizalde and Mansour, who enumerated Dumont permutations that avoided certain three or four letter patterns, and the work of Noonan and Zeilberger, who enumerated all permutations with one or two occurrences of some patterns. (Received September 17, 2013)

1096-05-2581 **Julianna S Tymoczko*** (jtymoczko@smith.edu), Department of Mathematics, 44 College Lane, Northampton, MA 01063. *Generalized splines and Schubert calculus.*

Splines are piecewise polynomials on polytopes that arise in many parts of applied mathematics, including computer graphics, numerical analysis, and PDEs. Billera pioneered the study of algebraic splines, which uses tools from commutative and homological algebra to attack combinatorial and algebraic questions about splines. Independently, algebraic geometers and topologists discovered that splines describe the equivariant cohomology rings of many important varieties.

In this talk, we describe a further generalization of splines, in which we loosen both the combinatorial condition inherent in "polytopes" and the algebraic condition from "piecewise polynomials". We then describe recent results due to many different people that construct bases for various modules of splines and show how these can be applied to problems in Schubert calculus. (Received September 17, 2013)

1096-05-2610 **Eric A Swartz*** (eric.swartz@uwa.edu.au), The University of Western Australia, School of Mathematics and Statistics, 35 Stirling Highway, Crawley, WA 6009, Australia. *New examples of strongly regular Cayley graphs.*

A graph Γ that is regular of degree k is said to be strongly regular if there exist integers λ and μ such that every two adjacent vertices have exactly λ common neighbors and every two nonadjacent vertices have exactly μ common neighbors. Given a group G and a subset S of elements of G, the Cayley graph $\mathrm{Cay}(G, S)$ has vertex set the elements of G, and $g, h \in G$ are adjacent vertices in $\mathrm{Cay}(G, S)$ if and only if $gh^{-1} \in S$. If for all $g \in S$ we have $g^{-1} \in S$, then $\mathrm{Cay}(G, S)$ is undirected. Very few examples of strongly regular Cayley graphs are known, and there are especially few known arising from nonabelian groups. In this talk, a new strongly regular Cayley graph $\mathrm{Cay}(G, S)$ is constructed for each extraspecial group of order p^3 and exponent p^2, where p is an odd prime, and a new general approach to finding these graphs is discussed. No previous knowledge of these topics will be assumed. (Received September 17, 2013)

1096-05-2612 **Edward Richmond***, Erichmond@math.ubc.ca, and **William Slofstra**. *Fiber bundle structures of Schubert varieties.* Preliminary report.

A theorem of Ryan and Wolper states that a type A Schubert variety is smooth if and only if it is an iterated fiber bundle of Grassmannians. We extend this theorem to arbitrary finite type, showing that a Schubert variety is smooth if and only if it is an iterated fiber bundle of Grassmannians of that type. These results depend on deep combinatorial results of Billey and Postnikov. (Received September 17, 2013)

1096-05-2617 **Christopher ONeill***, 3320 Adelaide Way, Belmont, CA 94002, and **Ezra Miller** and **Thomas Kahle**. *Binomial Irreducible Decomposition.*

A recent paper by Kahle and Miller introduces the notion of mesoprimary decomposition of monoid congruences, and uses it to give a combinatorial method for constructing primary decompositions of binomial ideals. In this talk, we extend this framework to construct irreducible decompositions of binomial ideals. (Received September 17, 2013)

1096-05-2624 **Nathan Reff*** (reff@alfred.edu), Division of Mathematics, Alfred University, Alfred, NY 14802. *Spectral Properties of Oriented Hypergraphs.*

An oriented hypergraph is a hypergraph where each vertex-edge incidence is given a label of $+1$ or -1. The adjacency and Laplacian eigenvalues of an oriented hypergraph are studied. Eigenvalue bounds for both the adjacency and Laplacian matrices of an oriented hypergraph which depend on structural parameters of the oriented hypergraph are found. An oriented hypergraph and its incidence dual are shown to have the same nonzero Laplacian eigenvalues. A family of oriented hypergraphs with uniformally labeled incidences is also studied. This family provides a hypergraphic generalization of the signless Laplacian of a graph and also suggests a natural way to define the adjacency and Laplacian matrices of a hypergraph. Some results presented generalize both graph and signed graph results to a hypergraphic setting. (Received September 17, 2013)

1096-05-2625 **Geir Agnarsson** and **Jill Bigley Dunham***, 401 Rosemont Ave, Frederick, MD 21701. *Conjectures and questions on coin graphs in the Euclidean plane.*

In 1946 Paul Erdős conjectured that the maximum number of the occurrences of the minimum distances between two points among a set of n points in the Euclidean plane is given by $m(n) = \lfloor 3n - \sqrt{12n-3} \rfloor$. This was proved by Heiko Harborth in 1974 who showed that $m(x)$ is exactly the maximum number of edges in a unit coin graph on n coins. In this talk we review some related conjectures on coin graphs in the plane and pose some natural generalizations of such questions, many of which have not yet been formally explored in the graph theory literature. (Received September 17, 2013)

1096-05-2642 **Zoltan Furedi** and **Zeinab Maleki***, zmaleki@math.iut.ac.ir. *On the maximum induced decomposition of graphs.*

We say a graph G admits an *induced decomposition* to a graph H if the edges of G can be partitioned to the induced copies of H. For example, for even number n, the complete graph K_n minus a one factor has an induced decomposition into $\binom{n/2}{2}$ four-cycles. The maximum number of edges in a graph on n vertices which admits an induced decomposition to a given graph H is denoted by $ex^*(n,H)$. This parameter investigated by Bondy and Szwarcfiter [J. Graph Theory, DOI: 10.1002/jgt.21654] and they determined the value of $ex^*(n,H)$ for all graphs with at most 4 vertices (and some other families). In this talk we present some upper and lower bounds for $\binom{n}{2}$- $ex^*(n, H)$, especially we prove that for every graph H, $O(n^{2-c})$ is an upper bound where $c=c(H)>0$. (Received September 17, 2013)

1096-05-2646 **Albert Gu*** (agu@andrew.cmu.edu). *Sprague-Grundy Values of the $\mathcal{R}$-Wythoff Game.*
We examine the Sprague-Grundy values of the game of $\mathcal{R}$-Wythoff, a restriction of Wythoff's game introduced by Ho, where tokens may not be taken from only the larger pile. Ho showed that the P-positions of $\mathcal{R}$-Wythoff agree with those of Wythoff's game, and found all positions of Sprague-Grundy value 1. We describe all the positions of Sprague-Grundy value 2, and also conjecture a general form of the positions of Sprague-Grundy value g. (Received September 17, 2013)

1096-05-2665 **Aihua Li*** (lia@mail.montclair.edu). *Recent Development of Randic Connectivity Index and Applications in Life Sciences.*
In this presentation the author will report recent results from the study of Randic connectivity indices (RCI) of certain graphs derived from biology and chemistry problems, including line graphs built from DNA sequences. Among a special type of graphs, the ones with maximum or minimum RCI value are identified. An application in DNA data analysis is shown which demonstrates how the graph index is used to analyze DNA data of Chagas disease and help better understand the revolutionary relationships of the insect vectors. (Received September 17, 2013)

1096-05-2752 **Amanda Ruiz*** (amruiz@hmc.edu). *Realization spaces of phased matroids.*
A phased matroid is a combinatorial abstraction of a finite set of vectors in complex space. The phased matroid is a tool for keeping track of some of the geometric information of the set of vectors. Just as complex numbers are an extension of real numbers, phased matroids are an extension of oriented matroids, which is a well studied field.

The realization space of an oriented (resp., phased) matroid is the space of vector arrangements in $\mathbb{R}^n$ (resp., $\mathbb{C}^n$) that correspond to oriented (resp., phased) matroid, modulo a change of coordinates. The realization space of any rank 2 oriented matroid is contractible. According to Mnëv's Universality Theorem, the realization spaces of oriented matroids with rank greater than or equal to 3 can be as complicated as any semi-algebraic variety. In fact, even uniform rank 3 oriented matroids can have a realization space homeomorphic to an (open) semi-algebraic variety.

In contrast, for uniform phased matroids which are not essentially oriented, the realization space is homeomorphically equivalent to $\mathbb{R}^{n-1}$ (where n is the number of elements of the phased matroid). (Received September 18, 2013)

06 ► Order, lattices, ordered algebraic structures

1096-06-922 **Michael R. DiPasquale*** (dipasqu1@illinois.edu), Department of Mathematics, 1409 W. Green St., Urbana, IL 61801. *Lattice-Supported Splines on Polytopal Complexes.*
The real vector space $C^r_k(\mathcal{P})$ of piecewise polynomial functions (splines) of smoothness r and degree $\leq k$ on a pure n-dimensional polytopal complex $\mathcal{P} \subset \mathbb{R}^n$ is of fundamental interest in approximation theory and numerical analysis. In the case where $\mathcal{P}$ is a simplicial complex and $k \geq 3r+2$ there is a basis for $C^r_k(\mathcal{P})$ which is 'locally supported' in the sense that each spline in the basis vanishes outside the star of a vertex [Ibrahim-Schumaker]. Such a basis is called a *star-supported* basis.

We show that there is an analog of star-supported bases for polyhedral complexes, which we call *lattice-supported* bases of $C^r_k(\mathcal{P})$. Each spline in a lattice-supported basis vanishes outside of a complex $\mathcal{P}_W$ which is associated to a flat W of the intersection lattice of interior codimension 1 faces of $\mathcal{P}$. In particular we show $C^r_k(\mathcal{P})$ has a lattice-supported basis for $k \gg 0$. In the planar case we conjecture a lower bound on k for when $C^r_k(\mathcal{P})$ has a lattice-supported basis. This is closely related to the question of finding $\dim_{\mathbb{R}} C^r_k(\mathcal{P})$ addressed in [Alfeld-Schumaker] and [McDonald-Schenck]. (Received September 11, 2013)

1096-06-1252 **Jason R Elsinger*** (jrelsing@ncsu.edu), Raleigh, NC 26703. *Classification of orbifold modules using twisted modules.*
Given an integral lattice L, one can construct a corresponding vertex algebra V using the Heisenberg algebra and the group algebra of L. Let T be an automorphism of V. The set of T-invariant elements is called an orbifold. C. Dong and others have used Zhu's algebra to classify all orbifold modules in the case $T = -1$. On the other hand, B. Bakalov and V. Kac have a way of constructing all possible twisted modules for any automorphism. In the case for an even positive definite integral lattice Q and an automorphism T of order 2, I use their construction to find all T-twisted modules and verify that there are no others using the works of C. Dong and others. These include, in particular, the root lattices for the simply-laced Lie algebras with a Dynkin diagram automorphism of order 2. (Received September 14, 2013)

1096-06-1984 **Jonathan David Farley*** (jonathan.farley@morgan.edu), Department of Mathematics, Morgan State University, 1700 E. Cold Spring Lane, Baltimore, MD 21251. *The Many Lives of Lattice Theory: An Expository Talk about Geometry, Topology, and Stanley.*

Modern lattice theory, the abstract study of order and hierarchy, was born at Harvard in the 1930's, a creation of Professor Garrett Birkhoff. His colleague Gian-Carlo Rota wrote, citing a prediction of I. M. Gelfand, that "lattice theory will play a leading role in the mathematics of the twenty-first century".

Using the g-Theorem on polytopes, Bjorner proved a result about how the number of totally ordered subsets of a finite distributive lattice grows as the subsets increase in size. He then asked in 1997 if that result could be proven combinatorially.

At "the other end of the galaxy," one finds Priestley duality for distributive lattices, finite or infinite, a way of understanding distributive lattice-ordered algebraic structures by means of topology.

One day, on an airplane crossing the Atlantic, I saw these two notions collide. (Received September 17, 2013)

1096-06-2055 **Martha Lee H Kilpack*** (martha.kilpack@oneonta.edu). *Closure Operators on a Subgroup Lattice.* Preliminary report.

Starting with a lattice which is isomorphic to a subgroup lattice, $Sub(G)$, we take all the closure operators on that lattice and create a new lattice, the lattice of closure operators of $Sub(G)$, $c.o.(Sub(G))$. We will consider the question, "Is $c.o.(Sub(G))$ also isomorphic to a subgroup lattice?" (Received September 17, 2013)

1096-06-2287 **William DeMeo*** (williamdemeo@gmail.com). *The Universal Algebra Calculator at the command line and in the cloud.* Preliminary report.

The Universal Algebra Calculator (UACalc) is a powerful computer algebra system used by researchers working in general (universal) algebra. It comes with an intuitive graphical user interface (gui) and runs on any computer with a Java runtime environment. For certain research objectives, however, it is inconvenient or impossible to use a gui, and we require a command line interface instead.

In this brief tutorial, we demonstrate the use of UACalc Java classes via the Jython command line interpreter on an ordinary Linux laptop. This allows us to exploit the power and speed of the UACalc library from the command line as well as from within Python programs. Moreover, a powerful local computer is not required, and we demonstrate that the computing can be done for free in the cloud (on Amazon EC2 servers) and controlled from any Android device.

Our demonstration of this cloud based computing solution for algebraic research will use examples that have contributed to progress on an important open problem in universal algebra and the theory of finite groups. (Received September 17, 2013)

08 ► General algebraic systems

1096-08-231 **Arthur D. Grainger*** (arthur.grainger@morgan.edu), 1221 Staint Andrews Way, Baltimore, MD 21239. *The Cardinality of $\beta_A(S_J)$.*

Let J be infinite and let $I = \mathcal{P}_f(J)$. Define $S_J = \{(i,f) \mid i \in I,\ f : \mathcal{P}(i) \to \mathcal{P}(i)\}$. For $(i,f),\ (k,g) \in S_J$, define $f * g : \mathcal{P}(i \cup k) \to \mathcal{P}(i \cup k)$ as follows. For $x \in \mathcal{P}(i \cup k)$, let $(f*g)(x) = g(x)$, if $x = \emptyset$; let $(f*g)(x) = g(x \cap k)$, if $x \cap k \neq \emptyset$; let $(f*g)(x) = f(x)$, if $x \in \mathcal{P}(i \backslash k)$ and $x \neq \emptyset$. Define $(i,f)*(k,g) = (i \cup k,\ f*g)$. $(S_J, *)$ is a semigroup. We consider $(\beta S_J, \circledast)$, the $Stone - \check{C}ech$ Compactification of the semigroup $(S_J, *)$ The collection $\{\beta_A(S_J) \mid A \in \mathcal{P}(J)\}$ is a partition of βS_J and the cardinality of $\beta_A(S_J)$ is $2^{2^{|J|}}$. (Received August 21, 2013)

1096-08-1163 **Chad R Mangum*** (cmangum2@ncsu.edu). *Twisted Toroidal Lie Algebras.*

This talk will discuss twisted toroidal Lie algebras, which are universal central extensions of twisted multi-loop algebras. This loop realization generalizes twisted affine Kac-Moody algebras (by adding more variables to the Laurent polynomials). The focus of this talk will be on the 2-toroidal case (that is, two variables) with a view toward both a different realization than the loop realization (the so-called Drinfel'd realization), as well as toward representations based on Feingold and Frenkel's representation of affine algebras as quadratic operators. Background and previous results inspiring the current talk (a specific realization in the nontwisted toroidal case, and a representation in the twisted affine and nontwisted toroidal cases) will be discussed as motivation to the extent time allows. This is joint work with Dr. Kailash Misra and Dr. Naihuan Jing. (Received September 17, 2013)

1096-08-1602 **Alyssa M Armstrong*** (amarmstr@ncsu.edu) and **Kailash C Misra** (misra@ncsu.edu). *Demazure Crystals for $U_q(D_4^{(3)})$.* Preliminary report.
We show that there exists a suitable sequence $\{w^{(k)}\}_{k\geq 0}$ of Weyl group elements for the perfect crystal $B = B^{1,3l}$ such that the path realizations of the Demazure crystals $B_{w^{(k)}}(l\Lambda_2)$ for the quantum affine algebra $U_q(D_4^{(3)})$ have tensor product-like structures with mixing index $\kappa = 1$. (Received September 16, 2013)

1096-08-2776 **Berhanu Bekele Belayneh*** (berhanufk@yahoo.co.uk), , Addis Ababa, Ethiopia. *A Solution Formula for finite-dimensional systems.*
We derive a direct solution formula for 2D discrete linear systems that are finite-dimensional as vector spaces, based on Hasse derivatives. This will provide a suitable framework for linear modeling in the discrete setting. (Received October 08, 2013)

11 ► Number theory

1096-11-78 **Adam Gamzon*** (adam.gamzon@gmail.com). *Average frequency of local torsion on abelian surfaces.*
Fix an integer $d \geq 1$. In 2008, David and Weston showed that, on average, an elliptic curve over $\mathbf{Q}$ picks up a nontrivial p-torsion point defined over a finite extension K of the p-adics of degree at most d for only finitely many primes p. We will discuss analogous averaging results for principally polarized abelian surfaces A over $\mathbf{Q}$ with real multiplication by $\mathbf{Q}(\sqrt{5})$ and a level-$\sqrt{5}$ structure and, more generally, for principally polarized abelian surfaces A over $\mathbf{Q}$ with a level-3 structure. Furthermore, we indicate how the result on abelian surfaces with real multiplication relates to the deformation theory of modular Galois representations. (Received July 14, 2013)

1096-11-98 **Bo-Hae Im*** (bohaeim@gmail.com), Dept. of Mathematics, Chung-Ang University, 84 Heukseok-Ro, Dongjak-Gu, Seoul, 156-756. *Elliptic curves and applications to concordant pairs within arithmetic progressions and in ratios.*
We prove that for a given positive integer M and an integer k, the number of strongly concordant pairs (m, n) with $m, n \in [1, N]$ and $m, n \equiv k \pmod{M}$ is at least $O(N)$, and we give a parametrization of them. This gives a parametrization of an infinite ramily of elliptic curves with pasotive rank over Q. Also we give a parametrization of θ-congruent numbers by using concordant pairs in ratio. (Received July 26, 2013)

1096-11-159 **Baiying Liu*** (liuxx969@umn.edu), Department of Mathematics, University of Utah, 155 S 1400 E Room 233, Salt Lake City, UT 84112. *On Extension of Ginzburg-Jiang-Soudry Correspondence to Certain Automorphic Forms on $Sp_{4mn}(\mathbb{A})$ and $\widetilde{Sp}_{4mn\pm 2n}(\mathbb{A})$.*
Let F be a number field, and $\mathbb{A} = \mathbb{A}_F$. In this paper, first, we provide a family of global Arthur parameters confirming all parts of a general conjecture on the relation between the structure of Fourier coefficients and the structure of global Arthur parameters, given by Jiang in 2012. Then we extend a correspondence between certain automorphic forms on $Sp_{4n}(\mathbb{A})$ and $\widetilde{Sp}_{2n}(\mathbb{A})$, given by Ginzburg, Jiang and Soudry in 2012, to certain automorphic forms on $Sp_{4mn}(\mathbb{A})$ and $\widetilde{Sp}_{4mn\pm 2n}(\mathbb{A})$, using the same idea of considering compositions of automorphic descent maps. (Received August 11, 2013)

1096-11-161 **Luis A. Lomelí*** (lomeli@math.ou.edu), Department of Mathematics, The University of Okalhoma, Norman, OK 73019-3103. *The Langlands-Shahidi method for the classical groups in positive characteristic and the Riemann Hypothesis.* Preliminary report.
We provide a definition for an extended system of γ-factors for products of generic representations τ and π of split classical groups or general linear groups over a non-archimedean local field of characteristic p. We prove that our γ-factors satisfy a list of axioms (under the assumption $p \neq 2$ when both groups are classical groups) and show their uniqueness (in general). This allows us to define extended local L-functions and root numbers. We then obtain automorphic L-functions $L(s, \tau \times \pi)$, where τ and π are globally generic cuspidal automorphic representations of split classical groups or general linear groups over a global function field. In addition to rationality and the functional equation, we prove that our automorphic L-functions satisfy the Riemann Hypothesis. (Received August 12, 2013)

1096-11-163 **Paul Pollack** (twonth@gmail.com), Department of Mathematics, University of Georgia, Athens, GA 30602, and **Carl Pomerance*** (carl.pomerance@dartmouth.edu), HB 6188, Dartmouth College, Hanover, NH 03755. *Paul Erdős and the rise of statistical thinking in elementary number theory.*

In ancient times mathematicians were fascinated with "special" numbers of all kinds, from primes, to perfects, amicables, abundants, and so on. For centuries, only the barest of attempts were made to systematically study their distribution within the natural numbers. About 200 years ago, the distribution of prime numbers began in earnest, and by the close of the nineteenth century, we had the prime number theorem. In the twentieth century, led principally by Paul Erdős, we began to study elementary number theory from this statistical viewpoint. One can see a direct progression, for example, from the ancient concepts of abundant and deficient numbers to distribution functions, the celebrated Erdős–Kac theorem, and the field of probabilistic number theory. In this talk, which celebrates the centennial anniversary of the birth of Paul Erdős, we shall see some of the triumphs of the this way of thinking about elementary number theory, and we shall see that this statistical viewpoint is flourishing. (Received August 12, 2013)

1096-11-193 **Alyson Deines***, adeines@uw.edu, and **Ben Lundell**. *Elliptic curve discriminant twins.*

Elliptic curves $E : y^2 = x^3 + Ax + B$ have an invariant called the discriminant $\Delta = -16(4A^3 + 27B^2)$. The discriminant roughly measures what happens when we view E over a finite field $\mathbb{F}_p$. The conductor N is another measure of $E(\mathbb{F}_p)$. We define $N = \prod p^{f_p}$ such that E has has bad reduction at p and f_p tells you what kind of bad reduction, i.e., $E(\mathbb{F}_p)$ has either a cusp or a node. Isogenous curves have the same conductor. I will explain how and when isogenous curves can have $N = \Delta$ and the surprising results about how often this can occur. (Received August 15, 2013)

1096-11-215 **Kevin Ford*** (ford@math.uiuc.edu), Department of Mathematics, University of Illinois at Urbana-Champaign, Urbana, IL 61801, **Florian Luca** (fluca@matmor.unam.mx), Fundación Marcos Moshinsky, Instituto de Ciencias Nucleares UNAM, Circuito Exterior, C.U., Apdo. Postal 70-543, D.F. 04510 Mexico, Mexico, and **Carl Pomerance** (carlp@gauss.dartmouth.edu), Department of Mathematics, Dartmouth College, Hanover, NH 03755-3551. *The range of Carmichael's universal exponent function.*

Let $\lambda(n)$ denote the maximal order of an element of the group $(\mathbb{Z}/n\mathbb{Z})^*$, commonly called Carmichael's function. We are concerned with estimating the function $V_\lambda(x)$ which counts the number of distinct values up to x in the image of λ. We show that $V_\lambda(x) = x(\log x)^{-c+o(1)}$, where $c = 1 - \frac{1+\log\log 2}{\log 2} \approx 0.08607$. (Received August 20, 2013)

1096-11-225 **Aseem Mukund Bhagwat*** (bhagwat.aseem@gmail.com), Room N-32, New Hostel, Indian Statistical Institute, 8th Mile, Mysore Road, Bangalore, Karnataka 560059, India. *Polygonal Numbers and Fermat's Last Theorem.* Preliminary report.

We begin with the elementary Diophantine x2 + y2 = z2 in positive integers, which we know has infinite solutions. Fermat's Last Theorem does not let us generalize this for higher powers. But we can generalize this for polygonal numbers; we can in fact prove that there are infinitely many n-gonal numbers which can be represented as a sum of m n-gonal numbers, for all m and n. Now, if we consider the above Diophantine for higher dimensional regular convex polytope numbers(squares above being two dimensional regular convex polytopes), we notice that there are special cases in each dimension where the solutions do not exist. As we see where the solutions exist and where they do not, we gain some new insights into Fermat's Last Theorem. We observe that Fermat's Last Theorem does not simply give us a family of Diophantine equations having no positive integer solutions, but something much more significant. Lastly, based on our insights, we ask a few questions, which if answered, could actually explain in a different way why Fermat's Last Theorem holds! (Received August 31, 2013)

1096-11-243 **Michael P. Knapp*** (mpknapp@loyola.edu). *2-Adic zeros of additive forms.*

In this talk, we determine the minimum number of variables needed to guarantee that a homogeneous polynomial of the form $a_1x_1^d + a_2x_2^d + \cdots + a_sx_s^d$, with integer coefficients, has a nontrivial 2-adic zero. (Received August 22, 2013)

1096-11-264 **Katherine Thompson*** (kthompson0721@gmail.com), Mathematics Department, University of Georgia, Athens, GA 30602. *Positive-Definite Quaternary Quadratic Forms Over $\mathbb{Q}(\sqrt{5})$.*

In this poster, we will show how to use the theory of local densities (developed by Siegel) and Hilbert modular forms to provide proofs of universality and almost-universality of quaternary positive-definite quadratic forms over $\mathbb{Q}(\sqrt{5})$. (Received August 25, 2013)

1096-11-266 **Fan Zhou*** (zhou.1406@math.osu.edu), 231 West 18th Ave, Columbus, OH 43202.
Sato-Tate Equidistribution of Satake Parameters. Preliminary report.

The 1978 Inventonis paper by Bruggeman firstly established the orthogonality relation between Fourier coefficients of Maass forms for SL(2,$\mathbb{Z}$) from the Kuznetsov trace formula. It has found numerous applications to various aspects of the theory of automorphic forms on GL(2).

We formulate a conjectured orthogonality relation between the Fourier coefficients of Maass forms on PGL(N). Based on the work of Goldfeld-Kontorovich and Blomer for N=3, and on our conjecture for N$\geq$ 4, we prove a weighted vertical equidistribution theorem (with respect to the generalized Sato-Tate measure) for the Satake parameter of Maass forms at a finite prime. (Received August 25, 2013)

1096-11-274 **Arindam Roy*** (roy22@illinois.edu), 1409 West Green Street, 273 Altgeld Hall, Urbana, IL 61801, and **Andrew Ledoan** and **Alexandru Zaharescu**. *Zeros of partial sums of the Dedekind zeta function of a cyclotomic field.*

The zeros of the partial sums of the Dedekind zeta function of a cyclotomic field K defined by the truncated Dirichlet series

$$\zeta_{K,X}(s) = \sum_{\|\mathfrak{a}\| \leq X} \frac{1}{\|\mathfrak{a}\|^s},$$

where the sum is to be taken over nonzero integral ideals $\mathfrak{a}$ of K and $\|\mathfrak{a}\|$ denotes the absolute norm of $\mathfrak{a}$. Specifically, we establish the zero-free regions for $\zeta_{K,X}(s)$ and estimate the number of zeros of $\zeta_{K,X}(s)$ up to height T. (Received August 26, 2013)

1096-11-338 **Greg Martin*** (gerg@math.ubc.ca), Department of Mathematics, UBC, Room 121, 1984 Mathematics Road, Vancouver, BC V6T 1Z2, Canada. *Squarefree values of trinomial discriminants.* Preliminary report.

The discriminant of a trinomial of the form $x^n \pm x^m \pm 1$ has the form $\pm n^n \pm (n-m)^{n-m} m^m$ if n and m are relatively prime. We investigate when these discriminants have nontrivial square factors. We explain various unlikely-seeming parametric families of square factors of these discriminant values: for example, when n is congruent to 2 (mod 6), we have that $((n^2-n+1)/3)^2$ always divides $n^n-(n-1)^{n-1}$. In addition, we discover many other square factors of these discriminants that do not fit into these parametric families. The set of primes whose squares can divide these sporadic values can be seen as a vast generalization of the Wieferich primes. We provide heuristics for the density of these "sporadic" primes and for the density of squarefree values of these discriminants. This is joint work with David Boyd and Mark Thom. (Received August 29, 2013)

1096-11-375 **Soohyun Park*** (soopark@mit.edu), 3 Ames St., Cambridge, MA 02139. *Arithmetic properties of generalized Fibonacci sequences.*

The *generalized* Fibonacci sequences are sequences $\{f_n\}$ which satisfy the recurrence $f_n(s,t) = sf_{n-1}(s,t) + tf_{n-2}(s,t)$ $(s,t \in \mathbb{Z})$ with initial conditions $f_0(s,t) = 0$ and $f_1(s,t) = 1$. In a recent paper, Amdeberhan, Chen, Moll, and Sagan considered some arithmetic properties of the generalized Fibonacci sequence. Specifically, they considered the behavior of an analogue of the p-adic valuation. In this paper, we resolve a conjecture which they raised relating to this topic. We also consider the rank modulo n in more depth and find an interpretation of the rank in terms of the order of an element in the multiplicative group of a finite field when n is an odd prime. Finally, we study the distribution of the rank over different values of s when $t=-1$ and suggest directions for further study involving the rank modulo prime powers of generalized Fibonacci sequences. (Received August 30, 2013)

1096-11-404 **John B. Friedlander*** (frdlndr@math.toronto.edu), Dept. of Computer and Mathematical Sciences, University of Toronto at Scraborough, Toronto, ON M1C 1A4, Canada. *Squares and Primes.*

We discuss a number of results obtained in works with different co-authors (H. Iwaniec, I. Shparlinski, T.D. Wooley). The problems considered all fall under the common theme of the application of sieve methods to the representation of integers in terms of squares and primes. (Received September 07, 2013)

1096-11-441 **James Maynard*** (maynard@maths.ox.ac.uk). *Sieve weights in the GPY method and small gaps between primes.*

Goldston, Pintz and Yıldırım introduced the 'GPY method' to show the existence of small gaps between primes, and this was spectacularly used in the recent breakthrough of Zhang. A key part of the GPY method is the use of Selberg-style sieve weights $w_n = (\sum_{d|P(n)} \lambda_d)^2$, where P is a fixed polynomial and λ_d are real constants which we can choose freely. If one restricts to a choice of λ_d of the shape $\lambda_d = \mu(d)f(d)$ with f a smooth function, then the optimal choice of f is given in terms of Bessel functions.

We introduce a different choice of weights which perform better than the Bessel function choice. One application of these weights shows that, under the Elliott-Halberstam conjecture, there are infinitely many pairs of primes which differ by at most 12 (the previous record being 16). (Received September 03, 2013)

1096-11-493 **Chantal David**, **Derek Garton**, **Zachary Scherr**, **Arul Shankar**, **Ethan Smith** and **Lola Thompson*** (lola.thompson@oberlin.edu). *Abelian surfaces over finite fields with prescribed groups.*

Let A be an abelian surface over $\mathbb{F}_q$. The rational points on $A/\mathbb{F}_q$ form an abelian group $A(\mathbb{F}_q) \simeq \mathbb{Z}/n_1\mathbb{Z} \times \mathbb{Z}/n_1n_2\mathbb{Z}\times\mathbb{Z}/n_1n_2n_3\mathbb{Z}\times\mathbb{Z}/n_1n_2n_3n_4\mathbb{Z}$. We are interested in knowing which groups of this shape actually arise as the group of points on some abelian surface over some finite field. For a fixed prime power q, a characterization of the abelian groups that occur was recently found by Rybakov. One can use this characterization to obtain a set of congruences modulo the integers n_1, n_2, n_3, n_4 on certain combinations of coefficients of the corresponding Weil polynomials. We use Rybakov's criterion to show that groups $\mathbb{Z}/n_1\mathbb{Z} \times \mathbb{Z}/n_1n_2\mathbb{Z} \times \mathbb{Z}/n_1n_2n_3\mathbb{Z} \times \mathbb{Z}/n_1n_2n_3n_4\mathbb{Z}$ do not occur if n_1 is very large with respect to n_2, n_3, n_4, and occur with density zero in a wider range of variables. (Received September 04, 2013)

1096-11-509 **David W Farmer**, **Steven M Gonek** and **Yoonbok Lee*** (lee@math.rochester.edu), Department of Mathematics, University of Rochester, Rochester, NY 14627. *Pair correlation of the zeros of the derivative of the Riemann ξ-function.*

The complex zeros of the Riemannn zeta-function are identical to the zeros of the Riemann xi-function, $\xi(s)$. Thus, if the Riemann Hypothesis is true for the zeta-function, it is true for $\xi(s)$. Since $\xi(s)$ is entire, the zeros of $\xi'(s)$, its derivative, would then also satisfy a Riemann Hypothesis. We investigate the pair correlation function of the zeros of $\xi'(s)$ under the assumption that the Riemann Hypothesis is true. We then deduce consequences about the size of gaps between these zeros and the proportion of these zeros that are simple. (Received September 05, 2013)

1096-11-539 **Ram M Murty** (murty@mast.queensu.ca), Department of Mathematics and Statistics, Jeffery Hall, University Ave., Kingston, Ontario K7L 3N6, and **Naomi Tanabe*** (naomi@mast.queensu.ca), Department of Mathematics and Statistics, Jeffery Hall, University Ave., Kingston, Ontario K7L 3N6, Canada. *Non-vanishing of derivatives of L-functions.* Preliminary report.

We report on some new results on the non-vanishing of derivatives of L-functions at the central point of symmetry. In particular, we discuss the case of the Dedekind zeta functions. This is joint work with Ram Murty. (Received September 05, 2013)

1096-11-542 **Peter J Cho*** (jcho23@buffalo.edu) and **Henry H Kim** (henrykim@math.toronto.edu). *Low lying zeros of Artin L-functions.*

With Malle's conjecture or a parametric polynomial, we construct families of Artin L-functions. For these families we prove one-level density results unconditionally or under reasonable assumptions. Our results shows that the symmetry type of these families agrees with the symplectic type. (Received September 05, 2013)

1096-11-552 **Bianca A. Thompson*** (bat7@hawaii.edu) and **Michelle Manes**. *Periodic points in towers of finite fields for polynomials associated to algebraic groups.*

We find the limiting proportion of periodic points in towers of finite fields for polynomial maps associated to algebraic groups, namely pure power maps $\phi(z) = z^d$ and Chebyshev polynomials. (Received September 05, 2013)

1096-11-553 **Levent Alpoge*** (alpoge@college.harvard.edu). *Self-conjugate core partitions and modular forms.*

A recent paper by Hanusa and Nath states many conjectures in the study of self-conjugate core partitions. We prove all but two of these conjectures asymptotically by number-theoretic means. We also obtain exact formulas for the number of self-conjugate t-core partitions for "small" t via explicit computations with modular forms. For instance, self-conjugate 9-core partitions are related to counting points on elliptic curves over Q with conductor dividing 108, and self-conjugate 6-core partitions are related to the representations of 11 mod 24s by $3X^2 + 32Y^2 + 96Z^2$, a form with finitely many (conjecturally five) exceptional integers in this arithmetic progression, by an ineffective result of Duke–Schulze-Pillot. (Received September 05, 2013)

1096-11-612 **Robert C Vaughan*** (rvaughan@math.psu.edu). *the general goldbach problem with beatty primes.*

In this talk we are concerned with the representation of large positive integers as the sum of a fixed number of prime numbers taken from Beatty sequences. We are able to avoid any conditions on the Beatty sequences that they be of finite type which have been required hitherto. We use a form of the Hardy-Littlewood-Vinogradov method, but the proofs are quite delicate. (Received September 07, 2013)

1096-11-631 **John C. Miller*** (jcmiller@math.rutgers.edu), Department of Mathematics, Rutgers University, Hill Center for the Mathematical Sciences, 110 Frelinghuysen Road, Piscataway, NJ 08854-8019. *Computing class numbers beyond Odlyzko's bounds: Real cyclotomic fields.*

Surprisingly, the class number of cyclotomic fields has only been determined for fields of rather small conductor, due to the difficulty of finding the "plus part" of the class number, i.e. the class number of the maximal real subfield. For example, prior to our recent work, the class number of the real cyclotomic fields of prime conductor had only been determined for primes up to 67 (or up to 163 if the GRH is assumed).

The main difficulties presented by these fields of larger conductor are that their Minkowski bounds are quite large, and their root discriminants are too large for the class number to treated by Odlyzko's discriminant bounds.

Our recent results have improved the situation. We have unconditionally proved that the class number of the real cyclotomic fields of prime conductor is 1 for primes up to 151. Furthermore, under the assumption of the GRH, we have calculated the class number of real cyclotomic fields up to prime conductor of 241.

This new technique should be applicable to any number field of moderately large discriminant, allowing us to confront the problem of determining the class number for a large class of number fields which so far have not been treatable by previously known methods. (Received September 08, 2013)

1096-11-640 **Daniel Parry*** (dtp29@drexel.edu), 33rd and Market Streets, Philadelphia, PA 19104. *A Polynomial Variation on Meinardus' Theorem.* Preliminary report.

Meinardus' Theorem is a standard tool in the analytic theory of partitions. As an application of the circle method, this theorem povides a connection between Dirichlet series $D(s) = \sum a_n/n^s$ and the Fourier coefficients

$$1 + \sum_{n=1}^{\infty} Q_n(z)q^n = \prod_{m=1}^{\infty} \frac{1}{(1-q^m)^{a_m}}.$$

During the study of polynomials associated with integer partition statistics, it has been discovered that an analogue of this theorem for polynomials with complex arguments. This talk will present sufficient conditions under which we can compute Fourier coefficients, $Q_n(z)$, which are generated by

$$1 + \sum_{n=1}^{\infty} Q_n(z)q^n = \prod_{m=1}^{\infty} \frac{1}{(1-zq^m)^{a_m}}$$

for a_m a real valued sequence for $z \in \mathbb{D}$. By using the circle method framework, we will sketch a proof that these hypothesis are indeed accurate and we will conclude with examples. (Received September 08, 2013)

1096-11-659 **Yeansu Kim*** (yeansu-kim@uiowa.edu), Department of Mathematics, 14 MacLean Hall, Iowa city, IA 52242. *L-functions from Langlands-Shahidi method and the generic Arthur packet conjecture.*

L-functions are very interesting tools that number theorists have been using since 18th century. Those also appear in the local Langlands conjecture. Briefly, the local Langlands conjecture asserts that there exists a 'natural' bijection between two different sets of objects: Arithmetic (Galois or Weil-Deligne) side and analytic (representation theoretic) side. In each side, we can define the L-functions of those objects. The L-functions from analytic side are defined by Shahidi (Langlands-Shahidi method) and the L-functions from arithmetic side are Artin L-functions. The natural question is whether two L-functions are equal through the local Langlands correspondence. If it is, we can use the properties of the L-functions from arithmetic side to study L-packet, the object in the analytic side, which is the set of irreducible admissible representations of quasi split group G over p-adic field. The equality of L-functions has an interesting application in proving the generic Arthur L-packet conjecture. The generic Arthur L-packet conjecture states that if the L-packet attached to Arthur parameter has a generic member, then it is tempered. In this talk, I will explain those in the case of split $GSpin$ groups. (Received September 08, 2013)

1096-11-681 **T. H. Le** and **Y.-R. Liu*** (yrliu@uwaterloo.ca). *Equidistribution of polynomial sequences in function fields.*

We prove a function field analog of Weyl's classical theorem on equidistribution of polynomial sequences. Our result covers the case when the degree of the polynomial is greater than or equal to the characteristic of the field, which is a natural barrier when one tries to apply the Weyl differencing process to function fields. We also discuss applications to van der Corput and intersective sets in function fields. (Received September 09, 2013)

1096-11-692 **Vincent J Pigno*** (pignov@math.ksu.edu), Department of Mathematics, Kansas State University, Manhattan, KS 66506. *The Lind-Lehmer Constant for Cyclic Groups of Order Less Than 892,371,480.*

Determining the Lind Lehmer constant for constant for the cyclic group $\mathbb{Z}_n$ when n is not a multiple of $892,371,480 = 2^3 \cdot 3 \cdot 5 \cdot 7 \cdot 11 \cdot 13 \cdot 17 \cdot 19 \cdot 23$. (Received September 17, 2013)

1096-11-699 **Hieu D Nguyen*** (nguyen@rowan.edu), Rowan University, Department of Mathematics, 201 Mullica Hill Rd., Glassboro, NJ 08028, and **Long Cheong**. *New Convolution Identities for Hypergeometric Bernoulli Polynomials.*

New convolution identities of hypergeometric Bernoulli polynomials are presented. Two different approaches to proving these identities are discussed, corresponding to the two equivalent definitions of hypergeometric Bernoulli polynomials as Appell sequences. Our results include formulas that extend those proven by K. Dilcher for classical Bernoulli polynomials and K. Kamano for hypergeometric Bernoulli numbers. (Received September 09, 2013)

1096-11-709 **Moshe Adrian*** (madrian@math.utah.edu) and **Baiying Liu** (liu@math.utah.edu). *Jacquet's conjecture on the local converse problem for epipelagic supercuspidal representations of GL(n,F).*

Let F be a non-archimedean local field of characteristic zero. For any irreducible admissible generic representation of GL(n,F), a family of twisted local gamma factors can be defined using Rankin-Selberg convolution or the Langlands-Shahidi method. Jacquet has formulated a conjecture on precisely which family of twisted local gamma factors can uniquely determine an irreducible admissible generic representation of GL(n,F). In joint work with Baiying Liu, we prove that Jacquet's conjecture is true for epipelagic supercuspidal representations of GL(n,F), supplementing recent results of Jiang, Nien, and Stevens. (Received September 09, 2013)

1096-11-724 **Chad Awtrey**, **Nicole Miles**, **Jonathan Milstead**, **Christopher Shill** and **Erin Strosnider*** (estrosnider@elon.edu). *Degree 14 2-adic fields.*

Fix a prime number p and a positive integer n. A foundational result in algebraic number theory states that there are only finitely many nonisomorphic extensions of the p-adic numbers of degree n. Many researchers have focused on developing methods for computing data about these extensions (such as Galois groups and ramification information). Previous research has completely classified all extensions up to and including degree 13. In this talk, we'll survey some of the past research related to computational p-adic field theory, and we will end by illustrating our techniques for classifying degree 14 extensions of the 2-adic numbers. (Received September 09, 2013)

1096-11-726 **Ayla R. Gafni*** (gafni@math.psu.edu). *Counting rational points near planar curves.*

We give an explicit asymptotic formula for the number of rational points near planar curves. More precisely, let $f : [\eta, \xi] \to \mathbb{R}$ have a continuous second derivative that is bounded away from 0 on $[\eta, \xi]$. For $Q \geq 1$ and $0 < \delta < 1/2$, define $N(Q, \delta)$ to be the number of rational points $(a/q, b/q) \in \mathbb{R}^2$ with $q \leq Q$, which lie in a δ-neighborhood of the curve graphing f. We provide an asymptotic formula for $N(Q, \delta)$, and show, under mild conditions on f, that

$$N(Q, \delta) \sim (\xi - \eta)\delta Q^2.$$

This result is relevant to the expansion of Khinchin Theory. If time permits, we will give a brief overview of Khinchin's theorem and its generalizations, and explain how this new result fits into the broader theory of metric Diophantine approximation. (Received September 09, 2013)

1096-11-798 **Joshua Harrington**, **Lenny Jones** and **Alicia Lamarche***, Shippensburg University, PA. *Representing Integers as the Sum of Two Squares in the Ring $\mathbb{Z}_n$.* Preliminary report.

A classical theorem in number theory states that a positive integer z can be written as the sum of two squares if and only if all prime factors q of z with $q \equiv 3 \pmod 4$ have even exponent in the prime factorization of z. One can consider a minor variation of this theorem by not allowing the use of zero as a summand in the representation of z as the sum of two squares. Viewing each of these questions in $\mathbb{Z}_n$, the ring of integers modulo n, we investigate which integers $n \geq 2$ are such that every $z \in \mathbb{Z}_n$ can be written as the sum of two squares in $\mathbb{Z}_n$. (Received September 11, 2013)

1096-11-803 **Chad Awtrey**, **Brett Barkley**, **Nicole Miles**, **Christopher Shill*** (cshill@elon.edu) and **Erin Strosnider**. *Computing Galois groups of degree 12 2-adic fields with trivial automorphism group.*

The p-adic numbers are a foundational tool in 21st century number theory. They also have practical applications in many fields including, cryptography and physics. Several researchers have focused on classifying extensions of the p-adic numbers by computing arithmetic invariants associated to each extension. Current research has classified all extensions up to and including degree 11. In this talk we will focus on degree 12 2-adic fields, considering only those with a trivial automorphism group. In particular we describe our method of computing the Galois groups of these extensions. (Received September 10, 2013)

1096-11-804 **Steven M. Gonek*** (gonek@math.rochester.edu), Department of Mathematics, University of Rochester, Rochester, NY 14627. *Finite Euler product approximations of the Riemann zeta-function.*

We discuss a family of approximations of the Riemann zeta-function and a closely related function formed from finite Euler products, the pole of the zeta-function at $s = 1$, and any zeros the zeta-function might have in the right half of the critical strip. The analysis is unconditional and suggests that if the Riemann Hypothesis is false, then the zeta-function's zeros "arise" in two ways. (Received September 10, 2013)

1096-11-827 **Ognian Trifonov*** (trifonov@math.sc.edu), Mathematics Department, University of South Carolina, Columbia, SC 29208. *Estimates for the number of lattice points close to a curve and applications.*

We prove new estimates for the number of lattice points close to a curve and use them to improve on a result of Luca and Shparlinski on the number of certain extremal finite fields, and to obtain formulas for the number of representations of integers as a difference of k-free number and a small prime. (Received September 10, 2013)

1096-11-856 **Xiaoyu He***, 282 Eliot Mail Center, Cambridge, MA 02138-7524. *Cross Number Invariants of Finite Abelian Groups.*

The cross number of a sequence over a finite abelian group G is the sum of the inverse orders of the terms of that sequence. We study two group invariants, the maximal cross number of a zero-sum free sequence over G, called $k(G)$, introduced by Krause, and the maximal cross number of a unique factorization sequence over G, called $K_1(G)$, introduced by Gao and Wang. Conjectured formulae for $k(G)$ and $K_1(G)$ are known, but only some special cases are proved for either. We show structural results about maximal cross number sequences that allow us to prove an inductive theorem giving conditions under which the conjectured values of k and K_1 must be correct for $G \oplus C_{p^\alpha}$ if they are correct for a group G. As a corollary of this result we prove the conjectured values of $k(G)$ and $K_1(G)$ for cyclic groups C_n, given that the prime factors of n are far apart. (Received September 10, 2013)

1096-11-897 **Daniel Fiorilli*** (fiorilli@umich.edu), **James Parks** (james.parks@uleth.ca) and **Anders Södergren**. *Low-lying zeros of elliptic curve L-functions: Beyond the ratios conjecture.*

We study the 1-level density of low-lying zeros of the L-functions attached to the family of quadratic twists E_d of a given elliptic curve E defined over $\mathbb{Q}$. For test functions whose Fourier transforms have sufficiently restricted support, we obtain an error term that is significantly sharper than the square-root cancellation predicted by the L-functions ratios conjecture of Conrey, Farmer and Zirnbauer. (Received September 11, 2013)

1096-11-954 **Katherine A Anders*** (kaanders@illinois.edu), 1409 W. Green St., MC-382, Urbana, IL 61801. *Properties of digital representations.* Preliminary report.

Let $\mathcal{A}$ be a finite subset of $\mathbb{N}$ including 0 and $f_{\mathcal{A}}(n)$ be the number of ways to write $n = \sum_{i=0}^{\infty} \epsilon_i 2^i$, where $\epsilon_i \in \mathcal{A}$. We will discuss asymptotics of the summatory function of $f_{\mathcal{A}}(n)$, as well as patterns and properties of sequences and polynomials arising from these digital representations. (Received September 11, 2013)

1096-11-967 **Yueke Hu*** (yhu@math.wisc.edu). *Cuspidal part of an Eisenstein series restricted to an index 2 subfield.*

Let E be a quadratic extension of a number field F. Let $E(g,s)$ be an Eisenstein series on $GL_2(E)$, and let f be a cuspidal automorphic form on $GL_2(F)$. We will consider in this talk the following automorphic integral:

$$\int_{Z_A GL_2(F)\backslash GL_2(A_F)} f(g)E(g,s)dg.$$

This is in some sense the compliment case to the well-known Rankin-Selberg integral and the triple product formula. We will approach this integral by Waldspurger's formula. We will see when the integral is automatically zero, and otherwise the L-function it represents. We will also show some local results at ramified places, where the level of the ramification can be arbitrarily large. (Received September 11, 2013)

1096-11-968 **Yueke Hu*** (yhu@math.wisc.edu). *An observation for the supercuspidal representation of GL_2 and its applications.*

In this talk, we will consider the Kirillov model of a supercuspidal representation of GL_2. We will see that when the central character of the representation is unramified or level 1, the change of the support of a Schwartz function in the model under the group action can be decided purely by its level. Then we will talk about its application to the study of local integrals for some automorphic integrals, including triple product L-function. (Received September 11, 2013)

1096-11-969 **Samuel S Gross*** (sgross@bloomu.edu) and **Michael Filaseta** (filaseta@math.sc.edu). *49598666989151226098104244512918.*

Let $f(x)$ be a polynomial with non-negative integer coefficients for which $f(10)$ is a prime. A result of A. Cohn implies that if the coefficients of $f(x)$ are ≤ 9, then $f(x)$ is irreducible. In 1988, M. Filaseta showed that the bound 9 can be replaced by 10^{30}. Can we do better? (Received September 11, 2013)

1096-11-970 **Zebediah Engberg*** (zeb@dartmouth.edu). *On the reciprocal sum of primes dividing Mersenne numbers.*

Let $f(n) = \sum_{p|2^n-1} 1/p$. Erdős proved that $f(n) \leq \log\log\log n + C$ for some constant C. Apart from the exact value of C, it is easy to show that this result is best possible. Although it would be more interesting to understand the maximal order of $\sum_{p|2^n-1} 1$, the function $f(n)$ is more tractable, albeit still difficult. In this talk, we consider Erdős's question on the exact value of the constant C, as well as functions which generalize $f(n)$. (Received September 11, 2013)

1096-11-1107 **Ping Ngai Chung*** (briancpn@mit.edu), 305 Memorial Drive, Cambridge, MA 02139, and **Shiyu Li**. *Bounded gaps between products of special primes.* Preliminary report.

In their breakthrough paper in 2006, Goldston, Graham, Pintz, and Yıldırım proved several results about bounded gaps between products of two distinct primes. Frank Thorne expanded on this result, proving bounded gaps in the set of square-free numbers with r prime factors for any $r \geq 2$, all of which are in a given set of primes. His results yield applications to divisibility of class numbers and triviality of ranks of elliptic curves. In this paper, we relax the condition on the number of prime factors and prove an analogous result using a modified approach. We then revisit Thorne's applications and give a better bound in each case. (Received September 12, 2013)

1096-11-1113 **A. Raghuram*** (raghuram@iiserpune.ac.in), Professor and Coordinator, Mathematics, Indian Institute of Science Ed. and Research, Dr. Homi Bhabha Road, Pashan, Pune, Maharashtr 411008, India. *Application of Langlands Functoriality to the special values of L-functions.* Preliminary report.

I will talk about some new developments concerning the special values of automorphic L-functions. One can use Langlands functoriality to prove rationality results for the special values of symmetric power L-functions attached to cusp forms on GL(2) over any number field. Even for the symmetric cube L-functions for cusp forms on GL(2) over a CM field such rationality results are new. (Received September 13, 2013)

1096-11-1186 **Amy T DeCelles*** (adecelles@stthomas.edu). *Designing Poincaré Series for Number Theoretic Applications.*

The GL_2 Poincaré series used to obtain the subconvexity results of Diaconu, Garrett, and Goldfeld can be viewed as a the solution to an automorphic partial differential equation, which can be constructed by winding-up the solution to the corresponding differential equation on the free space. Generalizing this approach has allowed us to design Poincaré series with specific number theoretic applications in mind: a Poincaré series for producing an explicit formula for the number of lattice points in an expanding region in a symmetric space and a Poincaré series suitable for producing moments of $GL_n \times GL_n$ L-functions. In this paper we present another Poincaré series designed for applications involving pseudo-Laplacians. (Received September 13, 2013)

1096-11-1220 **Jennifer L. Lansing*** (jlweber@illinois.edu). *On the Stern sequence and a related sequence.*

The author gives an introduction to the Stern sequence, some new results for the Stern sequence, and introduces a related sequence and some of its properties.

In 1858, Stern investigated a sequence of numbers, which he called the diatomic array, constructed in a way similar to Pascal's triangle: take two values a and b which form the first row, and form the next row by rewriting the previous row and inserting the sum $a+b$ between its summands. The Stern sequence is also defined by the recurrences $s(2n) = s(n)$, $s(2n+1) = s(n+1) + s(n)$ with $s(0) = 0$ and $s(1) = 1$. The diatomic array has many properties: the sum of values in a row is a power of 3, the largest value in a row is a Fibonacci number, every third term is even, and every number m will appear at most $\phi(m)$ times in a row. We give new results regarding the second and third distinct largest values in a row of the Stern sequence. We also discuss properties of a related sequence, defined as $w(n) := \frac{1}{2}s(3n)$. The sequence $w(n)$ inherits many similar properties to the Stern sequence, yet is more complicated in structure. This sequence has recurrence relations independent of $s(n)$, symmetry among values, and largest values related to Fibonacci numbers. (Received September 13, 2013)

1096-11-1239 **Benjamin Hutz*** (bhutz@fit.edu) and **Adam Towsley**. *Thurston's Theorem and Misiurewicz points for polynomial maps.*

The behavior of the critical points of a polynomial map plays an essential role in understanding its dynamics. We study the special case where the forward orbits of the critical points are finite. Thurston's theorem tells us that fixing a particular critical point portrait and degree leads to only finitely many possible polynomials (up to equivalence) and that their defining equations intersect transversely. We provide explicit algebraic formulae for the parameters where the critical points of the unicritical polynomials and bicritical cubic polynomials are specified exact period. We pay particular attention to the parameters where the critical orbits are strictly preperiodic called Misiurewicz points. Our main tool is the generalized dynatomic polynomial. We also provide an algebraic proof of Thurston's transversality result for the unicritical polynomials z^d+c. (Received September 13, 2013)

1096-11-1273 **Chad Awtrey*** (cawtrey@elon.edu). *A linear resolvent for degree 14 polynomials.*

Resolvent polynomials are an important tool in computational Galois theory. In this talk, we will focus on the construction and factorization pattern of a linear resolvent polynomial that is especially helpful for computing Galois groups of degree 14 polynomials. We include an algorithm for computing the Galois group of the normal closure of a degree 14 extension of the 7-adic numbers. (Received September 14, 2013)

1096-11-1286 **Hilary J. Smallwood*** (smallwood_h@hotmail.com). *Abelian Surfaces with Real Multiplication.* Preliminary report.

Given a simple abelian surface $A/\mathbb{F}_q$, the endomorphism algebra, $\mathrm{End}(A)\otimes\mathbb{Q}$, contains a real quadratic subfield. In this talk we will consider two different but related questions about when a particular real quadratic subfield K is the maximal real subfield of the endomorphism algebra. First we estimate the number of principally polarized abelian surfaces $A/\mathbb{F}_q$ such that $K \subset \mathrm{End}(A)\otimes\mathbb{Q}$, and show that this quantity is approximately $q^{5/2}$. Second we consider an abelian surface $A/\mathbb{Q}$, and its reduction $A_p = A \mod p$, then ask for which p does $K \subset \mathrm{End}(A_p)\otimes\mathbb{Q}$. The result from the first question leads to a heuristic for the second question, namely that the number of $p < x$ for which $K \subset \mathrm{End}(A_p)\otimes\mathbb{Q}$ grows like $\dfrac{\sqrt{x}}{\log x}$. (Received September 14, 2013)

1096-11-1404 **Dawn C. Nelson*** (dnelson@bates.edu). *A Variation on Leopoldt's Conjecture: Part 2.* Preliminary report.

What is the relationship between the (global) units of a number field and the (local) units of the related local fields? Leopoldt conjectured an answer. Informally his conjecture states that the $\mathbb{Z}_p$-rank of the diagonal embedding of the global units into the product of *all* local units equals the $\mathbb{Z}$-rank of the global units.

I consider the variation: Can we say anything about the $\mathbb{Z}_p$-rank of the diagonal embedding of the global units into the product of *some* local units? The answer is yes. In particular, in the case of an Abelian extension I use ideas from linear algebra, the theory of linear representations, and Galois theory to give a precise formula for the $\mathbb{Z}_p$-rank (of the diagonal embedding of the global units into the product of *some* local units) in terms of the $\mathbb{Z}$-rank of the global units and a property of the the local units included in the product. (Received September 15, 2013)

1096-11-1440 **Michael Filaseta*** (filaseta@math.sc.edu), Mathematics Department, University of South Carolina, Columbia, SC 29208. *The genus behind Hilbert's Irreducibility Theorem and/or a connection of this theorem to Linnik's result on the smallest prime in an arithmetic progression.*

One can take advantage of results associated with the genus of curves to explain Hilbert's Irreducibility Theorem in the form: if $f(x,y)$ is an irreducible polynomial in $\mathbb{Z}[x,y]$ of degree at least 1 in x, then there are infinitely many integers $y_0 \in \mathbb{Z}$ such that $f(x,y_0)$ is irreducible over $\mathbb{Q}$. This explanation will be elaborated on or the speaker may decide to talk instead on a connection that Linnik's theorem, on the smallest prime in an arithmetic progression, has with estimating the smallest $y_0 \in \mathbb{Z}^+$ such that $f(x) + y_0 g(x)$ is irreducible in $\mathbb{Z}[x]$, where $f(x)$ and $g(x)$ are fixed relatively prime polynomials in $\mathbb{Z}[x]$. Or then again, maybe the speaker will discuss both topics. (Received September 15, 2013)

1096-11-1484 **Kenneth Brown** and **Scott M. Dunn*** (scottmdunn@gmail.com), University of South Carolina, Department of Mathematics, 1523 Greene St., Columbia, SC 29208, and **Joshua Harrington**. *Arithmetic Progressions in the Polygonal Numbers.*

In this talk, we investigate arithmetic progressions in the polygonal numbers with a fixed number of sides. We first show that four-term arithmetic progressions cannot exist. We then describe explicitly how to find all three-term arithmetic progressions. Finally, we show that not only are there infinitely many three-term arithmetic progressions, but that there are infinitely many three-term arithmetic progressions starting with an arbitrary polygonal number. Special attention is paid to the case of squares and triangular numbers. (Received September 15, 2013)

1096-11-1489 **Morgan Cole** and **Scott M. Dunn*** (scottmdunn@gmail.com), University of South Carolina, Department of Mathematics, 1523 Greene St., Columbia, SC 29208, and **Michael Filaseta**. 8925840.

Let $f(x)$ be a polynomial with non-negative integer coefficients such that $f(b)$ is prime for some integer $b \geq 2$. A. Cohn's criteria states that if $b = 10$ and each coefficient is ≤ 9, then $f(x)$ is irreducible. In 1988, M. Filaseta showed that the bound 9 can be replaced by 10^{30}. We will look at work that was done to further increase this bound and then generalize this for an arbitrary base b. Along the way, we will also establish additional irreducibility criteria. (Received September 15, 2013)

1096-11-1490 **David Zureick-Brown*** (dzb@mathcs.emory.edu) and **Eric Katz**. *Rational points on curves and chip firing.*

Let X be a curve over $\mathbb{Q}$ with genus $g \geq 2$, $p > 2r$ a prime, J the Jacobian of X, $r = \text{rank } J(\mathbb{Q})$, and $\mathcal{X}$ a regular proper model of X at p. Suppose $r < g$. We prove that $\#X(\mathbb{Q}) \leq \#\mathcal{X}(\mathbb{F}_p) + 2r$, extending the refined version of the Chabauty-Coleman bound to the case of bad reduction.

In this talk I'll review the setup of Chabauty-Coleman and explain a new technical insight from tropical geometry which generalizes the classical rank of a divisor on a curve to a notion better suited for singular curves and which satisfies Clifford's theorem. (Received September 15, 2013)

1096-11-1499 **Laura Faber**, **Habiba Kadiri*** (habiba.kadiri@uleth.ca) and **Allysa Lumley**. *Explicit estimates for $\psi(x)$.*

In this talk we present some new Chebyshev bounds for the function $\psi(x)$. In 1962, Rosser and Schoenfeld provided a method to estimate the error term in the approximation $|\psi(x) - x|$. Since then, progress on the numerical verification of the Riemann Hypothesis and widening the zero-free region have allowed to improve numerically these bounds. In this talk we present a new method by introducing a smooth weight and by using the first explicit zero density estimate for the Riemann zeta function. We also present new results for primes in short intervals, based on this zero density estimate. (Received September 16, 2013)

1096-11-1572 **Chad Awtrey**, **Brett Barkley**, **Nicole Miles*** (nmiles@elon.edu), **Christopher Shill** and **Erin Strosnider**. *Classifying degree 12 2-adic fields with automorphism group of order 4.*

Let p be a prime number. The p-adic numbers were first introduced by K. Hensel toward the end of the 19th century. Since that time, they have become an important tool in many areas of number theory as well as mathematical physics. Recently, researchers have focused on classifying extensions of the p-adic numbers by computing invariant data that define each extension. Previous research has classified extensions through degree 11. In this talk, we discuss degree 12 extensions of the 2-adic numbers, focusing only on those extensions that have an automorphism group of order 4. We include a description of our method for computing the Galois groups of polynomials defining these extensions. (Received September 16, 2013)

1096-11-1580 **Bonita Lynn Graham*** (bgraham@wesleyan.edu). *A constuction of rigid analytic cohomology classes for split reductive linear algebraic groups.*

Ash and Stevens showed that it is possible to lift ordinary classical Hecke Eigensymbols on connected reductive groups to unique overconvergent Hecke Eigensymbols. Pollack and Pollack showed explicitly how to compute these lifts in the case of GL_3. I extend this constructive proof to any split connected reductive linear algebraic group G.

The key step is constructing a suitable filtration on D_λ, the space of p-adic distributions on weight λ functions on the big cell of G. An explicit formula for the filtration is given, allowing the computation of approximations of the overconvergent eigenclasses. (Received September 16, 2013)

1096-11-1636 **Berit Nilsen Givens*** (bngivens@csupomona.edu), 3801 W Temple Ave, Pomona, CA 91768. *The Chinese Remainder Theorem and knitting stitch patterns.*

The Chinese Remainder Theorem (CRT) is a classical result in number theory on the existence of solutions to systems of linear congruences. Many number theory textbooks present applications of the CRT that are either classical riddle problems or problems involving denominations of money. Interestingly, it turns out that the CRT can also be used to combine stitch patterns in knitting. The common knitting terminology used in stitch dictionaries can be rephrased as expressions in modular arithmetic. By constructing a system of linear congruence equations and using the CRT to solve them, a knitter can find the correct number of stitches to cast on to combine a variety of stitch patterns. This application can be interesting to number theory students who are looking for an example beyond the typical ones. In addition, we will discuss how to modify the problem when the congruence equations don't perfectly satisfy the hypotheses of the CRT, as well as ways in which the flexibility of real-world knitting does not exactly fit the world of number theory. (Received September 16, 2013)

1096-11-1668 **Jennifer Park***, Department of Mathematics, 77 Massachusetts Avenue, Cambridge, MA 02139. *Effective Chabauty for symmetric powers of curves.*

While we know by Faltings' theorem that curves of genus at least 2 have finitely many rational points, his theorem is not effective. In 1985, Coleman showed that Chabauty's method, which works when the Mordell-Weil rank of the Jacobian of the curve is small, can be used to give a good effective bound on the number of rational points of curves of genus $g > 1$. In this talk, we draw ideas from tropical geometry to show that we can also give an effective bound on the number of rational points of $\mathrm{Sym}^d(X)$ that are not parametrized by a projective space or a coset of an abelian variety, where X is a curve of genus $g > d$, when the Mordell-Weil rank of the Jacobian of the curve is at most $g - d$. (Received September 16, 2013)

1096-11-1696 **Gordan Savin** and **Michael C Woodbury*** (woodbury@math.columbia.edu), 2990 Broadway, MC 4430, New York, NY 10027. *Matching of Hecke operators for exceptional dual groups.*

Let $\mathbf{G}$ be a split algebraic group of type E_n defined over a p-adic field. This group contains a dual pair $G \times G'$ where one of the groups is of type G_2 . The minimal representation of G, when restricted to the dual pair, gives a correspondence of representations of the two groups in the dual pair. We prove a matching of spherical Hecke algebras of G and G', when acting on the minimal representation. This implies that the correspondence is functorial, in the sense of Arthur and Langlands, for spherical representations. (Received September 16, 2013)

1096-11-1826 **Silas Johnson*** (sjohnson@math.wisc.edu), University of Wisconsin, Department of Mathematics, 480 Lincoln Dr, Madison, WI 53706. *Alternate Discriminants and Mass Formulae for Number Fields.* Preliminary report.

Number fields are usually counted with the fields ordered by discriminant, but the discriminant can be viewed as one of a much larger class of invariants. Bhargava, Kedlaya, and Wood have studied the existence of a mass formula for the discriminant of local fields with certain Galois groups. We extend this work by studying mass formulae for other discriminant-like invariants. (Received September 16, 2013)

1096-11-1841 **George Grossman*** (gross1gw@cmich.edu), Department of Mathematics, Central Michigan University, Mount Pleasant, MI 48858, and **Tomas Zdrahal**, **Aklilu Zeleke** and **Xinyun Zhu**. *Recurrence relations and combinatorial identities.* Preliminary report.

In this paper we present the solution of pair of recurrence relations that subsequently yields various combinatorial identities, involving Fibonacci and Lucas numbers. Let $\alpha_1 = (b + \sqrt{b^2 + 4c})/(2c)$ and $\alpha_2 = (b - \sqrt{b^2 + 4c})/(2c)$ for real numbers $b, c,\ c \neq 0$. We show how an expression of the form $(\alpha_1^{n+1} - \alpha_2^{n+1})/(\alpha_1 - \alpha_2), n = 0, 1, 2, \ldots$ can be represented in countably many distinct, nontrivial ways, in terms of rational functions and binomial coefficients. (Received September 16, 2013)

1096-11-1934 **Hieu T Ngo*** (hieu@umich.edu), Dept. of Mathematics, Univ. of Michigan, 530 Church Street, Ann Arbor, MI 48109-1043. *The Lerch zeta function and the Eisenstein-Kronecker series.*

The Lerch zeta function is a three-variable generalization of the Riemann zeta function and the Hurwitz zeta function. It has an analytic continuation and a functional equation, but it lacks an Euler product and violates the Riemann hypothesis. In this talk we address the following questions:

(1) Is there a generalization of the Lerch zeta function for algebraic number fields?

(2) How does the Lerch zeta function relate to the Eisenstein-Kronecker series?

We supply some answers to these questions. (Received September 16, 2013)

1096-11-1971 **Thomas J Haines*** (tjh@math.umd.edu), Mathematics Department, University of Maryland, College Park, MD 20742, and **Benoit Stroh** (benoit.stroh@gmail.com), CNRS, LAGA, Université Paris 13, 99 avenue J.B. Clément, 93439 Villetaneuse, France. *Local models and nearby cycles for $\Gamma_1(p)$-level structure.*

This talk will discuss how to begin extending the theory of Rapoport-Zink local models of Shimura varieties, from those with $\Gamma_0(p)$- or parahoric-level structure, to those with $\Gamma_1(p)$-level structure. The analogue of the Kottwitz conjecture on nearby cycles, proved in the parahoric-level situation by Gaitsgory and Haines-Ngô, will also be discussed in this new context. The technique allows for the geometric construction via nearby cycles of many interesting central functions in a pro-p Iwahori-Hecke algebra of a group over a local function field, thereby extending Gaitsgory's results on Iwahori-Hecke algebras. (Received September 16, 2013)

1096-11-2024 **J. Brian Conrey*** (conrey@aimath.org), AIM, 360 Portage Ave, Palo Alto, CA 94306. *The mean square of the Riemann zeta-function and its twists.* Preliminary report.

In joint work with Sandro Bettin, we investigate the mean-square of the zeta-function on the critical line and its twists by $(h/k)^{it}$. These investigations have connections with zeros on the critical line, with the Riemann Hypothesis, and with the ratios conjecture. (Received September 17, 2013)

1096-11-2050 **DoYong Kwon*** (doyong@jnu.ac.kr), Department of Mathematics, Chonnam National University, Gwangju, 500-757, South Korea. *A one-parameter family of Dirichlet series whose coefficients are Sturmian words.*

Given $\alpha > 0$, let $(s_\alpha(n))_{n\geq 1}$ be the lexicographically greatest Sturmian word of slope α. We study Dirichlet series with $s_\alpha(n)$ coefficients. Its continuity and differentiability in α are investigated. As a consequence, we obtain another kind of singular function whose differentiability rests upon Diophantine approximation. (Received September 17, 2013)

1096-11-2107 **Daniel W. File*** (daniel.file@muhlenberg.edu), 2400 Chew St, Department of Mathematics and Computer Scienc, Allentown, PA 18104, and **Kimball Martin** (kmartin@math.ou.edu) and **Ameya Pitale** (apitale@math.ou.edu). *Test Vectors and Central L-values for GL(2).*

We determine local test vectors for Waldspurger functionals for GL(2), in the case where both the representation of GL(2) and the character of the degree two extension are ramified, with certain restrictions. We use this to obtain an explicit version of Waldspurger's formula relating twisted central L-values of automorphic representations on GL(2) with certain toric period integrals. As a consequence, we generalize an average value formula of Feigon and Whitehouse, and obtain some nonvanishing results. (Received September 17, 2013)

1096-11-2204 **Jonathan Bayless*** (baylessj@husson.edu) and **Dominic Klyve**. *New bounds and computations on prime-indexed primes.*

If the prime numbers are listed in increasing order, then the prime-index primes are those which occur in a prime-numbered position in the list. In 2009, Barnett and Broughan established a prime-index prime number theorem analogous to the standard prime number theorem. We improve and generalize their result with explicit bounds, bound the sum of reciprocals of prime-index primes, and present empirical results on prime-index prime versions of the twin prime conjecture and Goldbach's conjecture. (Received September 17, 2013)

1096-11-2233 **Carrie E. Finch**, **Lenny Jones** and **Dylan Sorge*** (finchc@wlu.edu). *Markov-Sierpiński numbers.* Preliminary report.

In 1962, J. Selfridge showed that 78557 has the property that for all natural numbers n, $78557\cdot 2^n+1$ is composite. Odd positive integers (such as 78557) with this property are called Sierpiński numbers in honor of W. Sierpiński's 1960 paper demonstrating their existence. In this talk, we discuss Sierpiński numbers in the sequence of Markov numbers. (Received September 17, 2013)

1096-11-2246 **Terrence Richard Blackman*** (terrence.blackman@du.edu), Katherine A. Ruffatto Hall, 335, 1999 E. Evans Ave., Denver, CO 80208. *Spectral correspondences on Quaternion Groups.*

We prove that in most cases the Jacquet-Langlands correspondence between newforms for Hecke congruence groups and newforms for quaternion orders is a bijection. Our proof covers almost all cases where the Hecke congruence group is of cocompact type, i.e. when a bijection is possible. The proof uses the Selberg trace formula for Hecke operators. (Received September 17, 2013)

1096-11-2278 **Tasho S Kaletha*** (tkaletha@math.princeton.edu). *Rigid inner forms and endoscopy.*

Adams, Barbasch, and Vogan defined the notion of a strong real form of a connected reductive group defined over the real numbers. It is a rigidification of the usual notion of an inner form and Vogan posed the problem of finding an analogous notion in the p-adic case. We will describe a new cohomology set for affine algebraic groups defined over local fields of characteristic zero. Its construction is uniform for real and p-adic groups and it leads to the notion of a rigid inner form which in the real case turns out to be equivalent to that of a strong real form. We will discuss applications to the internal structure of L-packets and the stabilization of the Arthur-Selberg trace formula (Received September 17, 2013)

1096-11-2291 **John J. B. Webb*** (webbjj@wfu.edu), PO Box 7388, 127 Manchester Hall, Winston-Salem, NC 27109, and **Jeremy Rouse**. *Eta-quotients and the $\mathbb{Q}$-rational cuspidal subgroup of $J_0(2^n)$.*

Let $\eta(z)$ be Dedekind's eta-function. For an integer $N \geq 1$, a function of the form $f(z) = \prod_{d|N} \eta(dz)^{r_d}$ with each $r_d \in \mathbb{Z}$ is called an eta-quotient; these functions have proved invaluable in the study of modular forms. We show that any modular form in the space $M_k(\Gamma_0(N))$ with integral Fourier coefficients which is non-zero on the upper-half plane is an eta-quotient, generalizing a result of Kohnen. As an application, we calculate the $\mathbb{Q}$-rational cuspidal subgroup of $J_0(2^n)$ for all $n \geq 1$. (Received September 17, 2013)

1096-11-2306 **Guillermo Mantilla-Soler*** (guillermo.mantilla@epfl.ch), EPFL – SB – MATHGEOM – CSAG, 1015 Lausanne, Vaud, Switzerland. *Weak arithmetic equivalence of number fields.*

Inspired by the invariant of a number field given by its Dedekind zeta function we define the notion of *weak arithmetic equivalence*, and we show that under certain ramification hypothesis this equivalence determines the local root numbers of the number field. This is analogous to a result Rohrlich on the local root numbers of a rational elliptic curve. Additionally we prove that for tame non-totally real number fields the integral trace form is invariant under weak arithmetic equivalence. (Received September 17, 2013)

1096-11-2337 **Andrew Granville*** (andgranville@gmail.com), University de Montreal, Pavillon Aisenstadt, Dept de mathematiques et de statistiques, CP 6128 Succursale Centre-Ville, Montreal, Quebec H3C 3J7, Canada. *Infinitely many pairs of primes differ by no more than 70 million (and the bound's getting smaller every day).*

One of the most famous problems about primes is the twin prime conjecture, which states that there are infinitely many pairs of primes that differ by 2. This is a strange problem in that primes are, by nature, a multiplicative construct (those numbers that are not the product of two other numbers > 1), whereas the twin prime conjecture asks about their additive structure. Perhaps this is what makes it so intriguing to amateur and professional mathematicians alike, yet professional mathematicians have mostly been deterred from working on it since they did not seem to have adequate tools to even formulate a plan to resolve the problem.

This all changed with the breakthrough paper of Goldston, Pintz and Yildirim (2009) who showed that if the primes are well enough distributed in arithmetic progressions then there are pairs of primes that differ by at most 16. At the time their proposed estimate seemed far off, yet last summer Yitang Zhang proved an estimate which, although weaker than proposed, still implies that there are infiniitely many pairs of primes that differ by no more than a certain given bound.

In this talk we will discuss the proof of this extraordinary result, and subsequent developments by a "polymath" project. (Received September 17, 2013)

1096-11-2345 **Abbey M Bourdon*** (abourdon@wesleyan.edu), Dept. of Mathematics and Computer Science, Wesleyan University, 265 Church Street, Middletown, CT 06459. *A Uniform Version of a Finiteness Conjecture for CM Elliptic Curves.*

Let A be an abelian variety of dimension g defined over a number field F. For a rational prime ℓ, we will denote the extension of F generated by the ℓ-powered torsion points of A by $F(A[\ell^\infty])$. According to a conjecture made by Rasmussen and Tamagawa in 2008, if $F(A[\ell^\infty])$ is both a pro-ℓ extension of $F(\mu_{\ell^\infty})$ and unramified away from ℓ, then $\ell \leq C(F, g)$, where $C(F, g)$ is a constant that depends only on F and g. We will show that if we restrict our attention to elliptic curves with complex multiplication, we can make $C(F, 1)$ explicit and, in fact, dependent only on the degree of the number field F. (Received September 17, 2013)

1096-11-2371 **Hugh L. Montgomery*** (hlm@umich.edu), Department of Mathematics, University of Michigan, 530 Church Street, Ann Arbor, OH 48109-1043, and **Steven M. Gonek**. *Large values of the zeta function at critical points.* Preliminary report.

Throughout, let $\rho' = \beta' + i\gamma'$ denote a zero of $\zeta'(s)$. Assuming the Riemann Hypothesis, we show that if $\beta' \geq 1$ and $4 \leq T \leq \gamma' \leq 2T$, then $|\zeta(\rho')| \leq \frac{1}{2}e^{C_0}\log\log T + O(1)$ where C_0 is Euler's constant. We conjecture that if $\beta' \geq 1$ and $4 \leq T \leq \gamma' \leq 2T$, then $\zeta(\rho')| \leq \left(\frac{1}{4}e^{C_0} + o(1)\right)\log\log T$. For all $T \geq 4$ we show unconditionally that there exists a ρ' with $\beta' \geq 1$ and $T \leq \gamma' \leq 2T$ such that $|\zeta(\rho')| \geq \left(\frac{1}{8}e^{C_0} - o(1)\right)\log\log T$. The proof of this depends on a quantitative version of Kronecker's theorem for inhomogenious Diophantine approximation. (Received September 17, 2013)

1096-11-2432 **Muthu Krishnamurthy*** (muthu-krishnamurthy@uiowa.edu). *Converse Theorems.* Preliminary report.

Converse Theorems for automorphic representations of GL(n) have generally been useful in establishing many instances of Langlands' functoriality conjecture. Over a number field with class number one, Cogdell and Piatetski-Shapiro proved a Converse Theorem using Rankin-Selberg twists by unramified automorphic representations of GL(n-1). I will report on my ongoing work with Andrew Booker which removes the class number restriction. (Received September 17, 2013)

1096-11-2529 **Yitang Zhang***, University of New Hampshire. *Small gaps between primes: A new method.*

The proof of the existence of infitely many pairs of primes whose gaps are bounded by a constant relies on the GPY sieve and a stronger version of the Bombieri-Vinogradov theorem. We introduce a new method which may be used to improve the existing results. The underlying idea is somewhat analogous to the circle method. We also discuss potential applications of this method to other problems, such as the existence of Goldbach numbers in short intervals. (Received September 17, 2013)

1096-11-2552 **Enrique Treviño***, 555 N. Sheridan, Lake Forest College, Department of Mathematics, Lake Forest, IL 60045, and **Paul P Pollack**. *The primes that Euclid forgot.*

Let $q_0 = 1$. Supposing that we have defined q_j for all $0 \leq j \leq k$, let q_{k+1} be a prime factor of $1 + \prod_{j=1}^{k} q_j$. As was shown by Euclid over two thousand years ago, $q_1, q_2, q_3, \ldots$ is then an infinite sequence of distinct primes. The sequence $\{q_i\}$ is not unique, since there is flexibility in the choice of the prime q_{k+1} dividing $1 + \prod_{j=1}^{k} q_j$. Mullin suggested studying the two sequences formed by (1) always taking q_{k+1} as small as possible, and (2) always taking q_{k+1} as large as possible. For each of these sequences, he asked whether every prime eventually appears. Recently, Booker showed that the second sequence omits infinitely many primes. We give a completely elementary proof of Booker's result. (Received September 17, 2013)

1096-11-2561 **Edray H Goins*** (egoins@math.purdue.edu), 150 North University Street, Mathematical Sciences Building, West Lafayette, IN 47907. *ABC Triples in Families.* Preliminary report.

Given three positive, relative prime integers A, B, and C such that the first two sum to the third i.e. $A + B = C$, it is rare to have the product of the primes p dividing them to be smaller than each of the three. In 1985, David Masser and Joseph Osterlé made this precise by defining a "quality" $q(P)$ for such a triple of integers $P = (A, B, C)$; their celebrated "ABC Conjecture" asserts that it is rare for this quality $q(P)$ to be greater than 1 – even through there are infinitely many examples where this happens. In 1987, Gerhard Frey offered an approach to understanding this conjecture by introducing elliptic curves. In this presentation, we introduce families of triples so that the Frey curve has nontrivial torsion subgroup, and explain how certain triples with large quality appear in these families. We also discuss how these families contain infinitely many examples where the quality $q(P)$ is greater than 1. (Received September 17, 2013)

1096-11-2576 **Scott T. Parsell*** (sparsell@wcupa.edu) and **Craig V. Spencer**. *Systems of Diophantine inequalities in function fields.* Preliminary report.

We obtain estimates for exponential sums over smooth polynomials in function fields and then adapt the circle method for function fields to investigate the solubility of systems of diagonal Diophantine inequalities of differing degree. (Received September 17, 2013)

1096-11-2702 **Jorge Dioses*** (jdioses@cottey.edu). *Numerical computations for a generalization of the theorem of Nakagawa on binary cubic forms.*

Using class field theory, J. Nakagawa was able to show that there is a correspondence between cubic fields of positive discriminant and cubic fields of negative discriminant. This relationship was explained in terms of class numbers of integral binary cubic forms. The works of B. Datskovsky and D. Wright suggested the possibility of a generalization of the result of Nakagawa to quadratic and cubic extensions of an arbitrary number field. There has been some progress in this direction including a conjecture by J. Dioses that is expressed as an equality of Dirichlet series. Even though a final proof is no available yet, there is strong numerical evidence for the proposed identity. In this presentation, we use existing tables of number fields and calculations of their splitting types at different places to check the conjecture expressed as an equality of finite sums of finite Euler products. (Received September 18, 2013)

1096-11-2764 **Lynnelle Ye*** (lynnelle@stanford.edu), 785 Northampton Drive, Palo Alto, CA 94303.
Bounding sums of the Möbius function over arithmetic progressions.

Let $M(x) = \sum_{1\le n\le x} \mu(n)$ where μ is the Möbius function. It is well-known that the Riemann Hypothesis is equivalent to the assertion that $M(x) = O(x^{1/2+\epsilon})$ for all $\epsilon > 0$. There has been much interest and progress in further bounding $M(x)$ under the assumption of the Riemann Hypothesis. In 2009, Soundararajan established the current best bound of

$$M(x) \ll \sqrt{x}\exp\left(\sqrt{\log x}(\log\log x)^c\right)$$

(setting c to 14, though this can be reduced). Halupczok and Suger recently applied Soundararajan's method to bound more general sums of of the Möbius function over arithmetic progressions, of the form

$$M(x;q,a) = \sum_{\substack{n\le x\\ n\equiv a \pmod q}} \mu(n).$$

They were able to show that assuming the Generalized Riemann Hypothesis, $M(x;q,a)$ satisfies

$$M(x;q,a) \ll_\epsilon \sqrt{x}\exp\left((\log x)^{3/5}(\log\log x)^{16/5+\epsilon}\right)$$

for all $q \le \exp\left(\frac{\log 2}{2}\lfloor(\log x)^{3/5}(\log\log x)^{11/5}\rfloor\right)$, a such that $(a,q)=1$, and $\epsilon > 0$.

In this paper, we improve Halupczok and Suger's work to obtain the same bound for $M(x;q,a)$ as Soundararajan's bound for $M(x)$, with no size restriction on the modulus q. (Received September 22, 2013)

12 ► Field theory and polynomials

1096-12-795 **Joshua Harrington** and **Lenny Jones*** (lkjone@ship.edu), Shippensburg University, PA. *A Class of Irreducible Polynomials.*

Let

$$f(x) = x^n + k_{n-1}x^{n-1} + k_{n-2}x^{n-2} + \cdots + k_1x + k_0 \in \mathbb{Z}[x],$$

where

$$3 \le k_{n-1} \le k_{n-2} \le \cdots \le k_1 \le k_0 \le 2k_{n-1} - 3.$$

We show that $f(x)$ and $f(x^2)$ are irreducible over $\mathbb{Q}$. Moreover, the upper bound of $2k_{n-1}-3$ on the coefficients of $f(x)$ is the best possible in this situation. (Received September 10, 2013)

1096-12-1013 **Caitlin King Stanton*** (cstanton@college.harvard.edu). *Packing Polynomials on Sectors of $\mathbb{R}^2$.*

If S is a region in the plane and I its set of lattice points, we say that a polynomial $P(x,y)$ is a packing polynomial on S if when we restrict $P(x,y)$ to I, the resulting map is a bijection to $\mathbb{N}$. Fueter and Pólya showed that when S is the first quadrant, there are exactly two quadratic packing polynomials. In this talk we give a necessary condition for the existence of quadratic packing polynomials on rational sectors, and determine all quadratic packing polynomials on integral sectors. (Received September 12, 2013)

1096-12-1062 **T. Alden Gassert*** (gassert@math.umass.edu), Lederle Graduate Research Tower, Department of Mathematics and Statistics, 710 N. Pleasant St, Amherst, MA 01003.
Chebyshev action on finite fields.

Given a polynomial ϕ and a finite field $\mathbb{F}_q$ one can construct a directed graph where the vertices are the values in the finite field, and emanating from each vertex is an edge joining the vertex to its image under ϕ. When ϕ is a Chebyshev polynomial of prime degree, the graphs display an unusual degree of symmetry. In this paper we provide a complete description of these graphs, and then use these graphs to determine the decomposition of primes in the Chebyshev radical extensions. (Received September 12, 2013)

1096-12-1458 **Keenan Monks*** (monks@college.harvard.edu), 293 Dunster Mail Center, Cambridge, MA 02138. *Kernel Polynomials of Tile Digit Sets.*

Let $\mathcal{D} \subset \mathbb{Z}^+$ be a set of size b. By studying the possible *kernel polynomials* of the mask polynomials of $\mathcal{D}$, Lai, Lau, and Rao showed that, for $b = p^\alpha q$ for primes p, q, $\mathcal{D}$ is a tile digit set if and only if is a modulo product-form of some order. We generalize their methods to classify the kernel polynomials of tile digit sets for the case $b = p^2q^2$. (Received September 15, 2013)

1096-12-1659 **Chris Castillo*** (castillo@math.udel.edu) and **Robert S. Coulter** (coulter@math.udel.edu). *Representing groups by permutation polynomials.*

Cayley's Theorem guarantees that any group can be represented as a permutation group. In particular, when we take the set being permuted to be a finite field $\mathbb{F}_q$, we can use the Lagrange Interpolation Formula to construct a polynomial which represents a given permutation. Such polynomials, whose induced function defines a bijection of $\mathbb{F}_q$, are called permutation polynomials. A central problem in the theory of finite fields is to discover new classes of permutation polynomials.

In this talk, we introduce a new technique for constructing groups of permutation polynomials using group actions. As an application of this method, we construct a new class of permutation polynomials over the field $\mathbb{F}_{p^2}$ for any odd prime p using the regular action of the cyclic group of order p^2 on itself. The construction method guarantees that the set of permutation polynomials so obtained naturally forms a cyclic group, where the group operation is composition of polynomials in $\mathbb{F}_{p^2}[X]$ reduced modulo $X^{p^2} - X$. Moreover, every non-identity permutation polynomial generated by this method is fixed-point free. (Received September 16, 2013)

13 ► Commutative rings and algebras

1096-13-130 **Daniel R. Carmody** (dcarmody@indiana.edu), Department of Mathematics, Indiana University, Bloomington, IN 47405, **Susan M. Cooper** (s.cooper@cmich.edu), Department of Mathematics, Central Michigan University, Mt. Pleasant, MI 48859, **Nicholas A. Crispi*** (ncrispi@hunter.cuny.edu), Department of Mathematics and Statistics, Hunter College, CUNY, 695 Park Avenue, New York, NY 10065, and **Marie N. Ermete** (ermet1mn@cmich.edu), Department of Mathematics, Central Michigan University, Mt. Pleasant, MI 48859. *Fat Points on Grids and Hamming Distance.* Preliminary report.

Relationships between reduced sets of points in projective space and associated linear codes have been explored by a number of experts in the areas of algebraic geometry, commutative algebra, and coding theory. However, only recently these explorations have been extended to include special non-reduced points called *fat point schemes* obtained by adding multiplicities to the points. The majority of the results in this direction have been for homogeneous fat point schemes (i.e., in the case where each point has the same multiplicity). In this talk we consider generalizing the framework to non-homogeneous fat point schemes in projective 2-space. We will show that a certain type of fat point scheme supported on a grid complete intersection has the same resolution as a special partial intersection (a special reduced point set) and then connect this resolution to the minimum Hamming distance of the linear code constructed from the fat point scheme. This research was completed as part of the Central Michigan University REU program. (Received August 02, 2013)

1096-13-202 **Olivier A. Heubo-Kwegna***, 7400 Bay Road, Department of Mathematical Sciences, Saginaw Valley State University, University Center, MI 48710. *On Local *-Completely Integrally Closed Domains.*

Let $\star$ be a star operation on an integral domain R. The domain R is a $\star$-completely integrally closed domain (or simply $\star$-CICD) if $(AA^{-1})^\star = R$ for all nonzero (fractional) ideals A of R. In this talk, we discuss $\star$-CICDs, especially the local case. We show that if the maximal ideal of a local $\star$-CICD is a $\star$-ideal, then R is $\star$-principal ideal domain. This will lead as consequences to various results on local Krull domains and local completely integrally closed domains. We also establish that any $\star$-CICD R is locally a PID when $\star$ is induced by the localizations at prime ideals of R. (Received August 16, 2013)

1096-13-377 **Irena Peeva***, irena@math.cornell.edu, and **David Eisenbud**, de@msri.org. *Applications of CI Matrix Factorizations.* Preliminary report.

Matrix factorizations of a hypersurface yield a description of the asymptotic structure of minimal free resolutions over the hypersurface. We have introduced a new functorial concept of matrix factorizations for complete intersections which allows us to describe the asymptotic structure of minimal free resolutions over complete intersections. This talk will discuss applications of such matrix factorizations. (Received August 31, 2013)

1096-13-389 **Juergen Herzog** and **Craig Huneke*** (huneke@virginia.edu), Department of Mathematics, P.O. Box 400137, University of Virginia, Charlottesville, VA 22904. *Powers of ideals and Golod rings.*

We present work done jointly with J. Herzog, concerning quotient rings of regular rings which are Golod. In particular, we sketch the main ideas of why quotients with defining ideals which are higher powers, symbolic powers, or saturations are Golod. We also discuss some still open questions. (Received September 01, 2013)

1096-13-409 **Adam Boocher*** (aboocher@math.berkeley.edu) and **Federico Ardila** (federico@sfsu.edu). *The Closure of a Linear Space in* $(\mathbb{P}^1)^n$.

If $L \subset \mathbb{A}^n$ is a linear space then we can take its closure in $(\mathbb{P}^1)^n$ once we fix coordinates. In this talk I'll present joint work with Federico Ardila concerning the defining ideal I of the closure. It turns out the combinatorics of this ideal are completely determined by a matroid associated to L. We compute I explicitly as well as its degree, universal Gröbner basis, and initial ideals - all with a few ideas from matroid theory. (Received September 02, 2013)

1096-13-501 **Hop Dang Nguyen** and **Thanh Quang Vu*** (vqthanh@math.berkeley.edu). *Koszul algebras and the Frobenius endomorphism.*

Let R be a standard graded algebra over a field of characteristic $p > 0$. Let $\varphi : R \to R$ be the Frobenius endomorphism. For each finitely generated graded R-module M, let ${}^{\varphi}M$ be the abelian group M with an R-module structure induced by the Frobenius endomorphism. The R-module ${}^{\varphi}M$ has a natural grading given by $\deg x = j$ if $x \in M_{jp+i}$ for some $0 \leq i \leq p-1$. In this talk, I will present a new criterion of Koszul algebras: R is Koszul if and only if there exists a non-zero finitely generated graded R-module M such that $\operatorname{reg}_R {}^{\varphi}M < \infty$. We derive this analog of Kunz's regularity criterion in positive characteristic by developing a theory of Castelnuovo-Mumford regularity over homomorphisms between $\mathbb{N}$-graded k-algebras, where k is a field of arbitrary characteristic. (Received September 05, 2013)

1096-13-604 **Javid Validashti*** (jvalidas@illinois.edu). *Multiplicity Sequence of Graded Algebras.* Preliminary report.

Let $A \subset B$ be a homogeneous inclusion of finitely generated standard graded algebras over a Noetherian local ring. We define a sequence of numbers for the pair $A \subset B$ that unify several notions of multiplicities, including the Buchsbaum-Rim multiplicity of modules or more generally the relative multiplicities of Simis, Ulrich and Vasconcelos, the j-multiplicity of ideals introduced by Achilles and Manaresi as well as the j-multiplicities of the pair $A \subset B$ defined by Ulrich and Validashti, and the multiplicity sequence of an ideal described by Achilles and Manaresi. Using our invariants, we study numerical criteria for integrality of the extension $A \subset B$. (Received September 07, 2013)

1096-13-615 **Stefan O Tohaneanu*** (tohaneanu@uidaho.edu), Department of Mathematics, University of Idaho, 875 Perimeter Drive MS 1103, Moscow, ID 83844-1103. *Ideals generated by products of linear forms.* Preliminary report.

Let $L_1, \ldots, L_n \in R := \mathbb{K}[x_0, \ldots, x_k]$ be n linear forms with $\gcd(L_i, L_j) = 1, i \neq j$. In R consider the ideals $I_j, j = 1, \ldots, n$ generated by all distinct $j-$products of $L_1, \ldots, L_n$; i.e.

$$I_j = \langle \{L_{i_1} L_{i_2} \cdots L_{i_j}\}_{1 \leq i_1 < i_2 < \cdots < i_j \leq n} \rangle.$$

These ideals occur naturally in the study of star configurations, subspace (or hyperplane) arrangements, or in coding theory, and they contain lots of information about the objects to which they are associated. For example, if $\mathcal{A}$ is the hyperplane arrangement defined by the L_i's, I_{n-1} helps decide if a coatom in the intersection lattice of $\mathcal{A}$ is modular or not. In coding theory the heights of the ideals I_j help determine the minimum distance of linear codes. As a consequence of this one can obtain results concerning the Waring Problem for completely decomposable tensors. I will discuss about these properties, the goal being to review, if possible, all of the results in regard to this type of ideals. (Received September 07, 2013)

1096-13-673 **Hongbo Li*** (hli@mmrc.iss.ac.cn), Academy of Mathematics and Systems Science, C, Beijing, Beijing 100190, Peoples Rep of China, and **Changpeng Shao** and **Lei Huang**. *The Gröbner Basis Theory of Bracket Polynomials.*

In classical invariant theory, a bracket is the determinant of the coordinates of n vectors in an nD vector space, and all invariants under $GL(n)$ are polynomials of the brackets, called bracket polynomials.

While addition and multiplication among bracket polynomials are easy when the input and output are both in normal form, division of a bracket polynomial by another, or more generally, by finitely many bracket polynomials, is highly nontrivial. The division requires both the quotient(s) and the remainder to be bracket polynomials, and the order of the remainder to be not higher than the input bracket polynomial. The division is indispensible for obtaining invariant results by algebraic manipulations among classical invariants.

In this talk, we introduce our recent work of establishing the Gröbner basis theory of bracket polynomials. We start with a discovery of an admissible order among bracket monomials, i.e., if $f \prec g$ then $fh \prec gh$ for nonzero f, g, h. Then we proceed to define the division operation among bracket polynomials. And then we investigate the least common multipliers of two bracket polynomials, which turn out to be not unique but finite. With these preparations we are able to establish the Buchberger algorithm for bracket polynomials. (Received September 09, 2013)

1096-13-746 **Robert Rapael***, raphael@alcor.concordia.ca. *The reflection of certain categories of domains in the category of commutative semiprime rings.* Preliminary report.

This is a report of work in progress with M. Barr and J. Kennison.

For the special session on categorical topology.

One reflects into the category of semiprime rings a full subcategory, for example that of domains, that of integrally closed domains, and others. The reflection is described and there are nice descriptions of how a ring since inside its reflection. (Received September 09, 2013)

1096-13-785 **Trevor McGuire*** (`tmcgui1@lsu.edu`). *Combinatorial Algorithms for Generating Free Resolutions of Ideals with Binomials and Monomial Generators.*

In recent years, the combinatorial properties of monomials ideals and binomial ideals have been widely studied. In particular, combinatorial interpretations of free resolution algorithms have been given in both cases. In this presentation, we will introduce a similar combinatorial algorithm that will generate free resolutions of ideals with both binomial and monomial generators. The algorithm will reduce to the aforementioned algorithms in the case where only one type of generator is present. (Received September 10, 2013)

1096-13-813 **Sander Mack-Crane*** (`mack-crane@case.edu`) and **Samuel Tripp**. *Local Generic Formal Fibers of Excellent Rings.*

Given a local Noetherian ring, we can define a new ring which we call its completion. One interesting relationship between a ring and its completion is the generic formal fiber. We will discuss the existence of excellent rings of characteristic 0 possessing a local generic formal fiber, and present original results and conjectures regarding the existence of excellent rings possessing a local generic formal fiber in characteristic greater than 0. (Received September 10, 2013)

1096-13-834 **Fulton L. Jackson II*** (`fjacks14@msudenver.edu`). *A Classification Theorem for Diophantine Monoids with Special Defining Matrices.*

In the paper *"Factorization Theory and Decomposition of Modules"* N. R. Baeth and R. Wiegand describe the connections between the KRSA Decomposition Theorem and factorization results within integral domains. Their paper concludes with a series of open questions on how these results can be extended. In this presentation we propose our solution for the classification problem of Diophantine monoids.

In order to describe what monoids H can be realized as Diophantine monoids with special properties we studied the row-reduced form of the defining matrix φ_H. After completely classifying these monoids we conclude our presentation with a list of characteristics for Diophantine monoids and extend our results to indecomposable modules. (Received September 10, 2013)

1096-13-981 **YI ZHANG***, 1409 W Green Street, Urbana, IL 61821. *Toward an efficient algorithm for deciding the vanishing of local cohomology modules in prime characteristic.*

Let $R = k[x_1, \cdots, x_n]$ be a polynomial ring over a field k of characteristic $p > 0$. If I is an ideal of R, we denote $H^i_I(R)$ the i-th local cohomology module of R with support in I. We describe an algorithms to determine the vanishing of $H^i_{\mathfrak{m}}(H^j_I(R))$, where $\mathfrak{m} = (x_1, \cdots, x_n)$. The method we use is the F-module theory. (Received September 11, 2013)

1096-13-985 **Stepan Paul*** (`stpaul@calpoly.edu`), Department of Mathematics, California Polytechnic State University, San Luis Obispo, CA 93407. *A combinatorial duality theorem for syzygies of Veronese ideals of weighted projective space.*

We prove a purely combinatorial duality theorem for the reduced homology groups of a certain class of simplicial complexes. Sturmfels showed how to use these reduced homology groups to calculate the multigraded Betti number of toric ideals; for the ideals of Veronese embeddings weighted projective space, we are able to give a dual formula. We use this duality to show how close to being Gorenstein the quotients by these Veronese ideals are. We also give a combinatorial formula for the rank of the highest nonzero syzygy of these Veronese ideals. (Received September 12, 2013)

1096-13-1085 **Michael Axtell**, **Nicholas Baeth** and **Joe Stickles*** (jstickles@millikin.edu).
Graphical Representations of Factorizations in Commutative Rings.

We survey the recent and active area of irreducible divisor graphs of commutative rings. Notable algebraic and graphical results are given, and alternate constructions for irreducible divisor graphs and higher dimensional analogs are explored. (Received September 12, 2013)

1096-13-1317 **Kuei-Nuan Lin*** (klin@smith.edu) and **Paolo Mantero**. *Projective Dimension of Hypergraphs.* Preliminary report.

We find an exclusive formula to compute the projective dimension of square-free monomial ideals. We associate square-free monomial ideals with hypergraphs that is first introduced by Kimura-Terai-Yoshida. We write the projective dimension of string or cycle hypergraphs in terms of invariants of hypergraphs. As an application, we characterize all the string or cycle hypergraphs whose associated square-free monomial ideals are Cohen-Macaulay. This is joint work with Paolo Mantero. (Received September 14, 2013)

1096-13-1378 **H. Ananthnarayan** and **Ela Celikbas*** (celikbase@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211, and **Zheng Yang**. *Connected sums of k-algebras.*

A connected sum, initially introduced by H. Ananthnarayan, L. Avramov, and F. Moore, is a construction that can be used to produce Gorenstein rings. In this talk we discuss a characterization of connected sums of k-algebras, and some relations between associated graded rings and connected sums. In particular, we observe that a Gorenstein Artin k-algebra is a connected sum with certain conditions on its associated graded ring. We also show some applications of this result. (Received September 16, 2013)

1096-13-1415 **David Eisenbud*** (de@msri.org). *Residual Intersections and Duality.* Preliminary report.

Some 25 years ago Duco van Straten proved a surprising generalization of a basic result on duality: if J=(f1,..,fd) is an ideal of dimension 1 in a d-dimensional power series ring, and I is the unmixed part of J, then I/J is self-dual. Around the same time, Craig Huneke and Bernd Ulrich showed that the canonical module of a (sufficiently nice) residual intersection could be expressed in terms of certain powers of the ideals involved. Ulrich and I recently understood how these results fit together in a general duality theorem for (sufficiently nice) residual intersections. I will explain this group of results. (Received September 15, 2013)

1096-13-1439 **Sema Gunturkun*** (gunturkun@ms.uky.edu) and **Uwe Nagel** (uwe.nagel@uky.edu). *A Construction for Homogeneous Gorenstein Ideals.* Preliminary report.

For given Gorenstein ideals $\mathfrak{b} \subset \mathfrak{a}$ in a local Gorenstein ring R, a construction of Gorenstein ideal in $R[v]$ from the ideals $\mathfrak{a}, \mathfrak{b}$ is shown by A. Kustin and M. Miller in 1983. We adjust their construction to the case of graded rings and modify it by avoiding ring extensions. We also see how liaison theory plays an important role in this construction. (Received September 15, 2013)

1096-13-1500 **Juan Felipe Perez*** (juanfp@umich.edu), 530 Church Street, Ann Arbor, MI. *A Charaterization of F-jumping Numbers.*

The F-jumping numbers are invariants associated to singularities in positive characteristic. In order to study these invariants Blickle, Mustata and Smith introduce the D-modules M_α. We prove that the simplicity of these modules determines if α is an F-jumping number. This is joint work with Luis Núñez-Betancourt. (Received September 16, 2013)

1096-13-1620 **A. K. Wheeler*** (wheeles@umich.edu). *Ideals Generated by Principal Minors.*

Let K be an algebraically closed field. We study the algebraic sets defined by the vanishing of the size t principal minors of a size n square matrix of indeterminates, and the varieties which are irreducible components of these algebraic sets. In the case where $t = 2$ these are normal complete intersections with coordinate ring isomorphic to a semigroup ring. The general behavior is much more complicated. We give bounds on the height of the defining ideal and show, for example, that for $n \geq 4$ and $t = n-1$ there are two components, one of codimension 4 and the other of codimension n. Thus, when $n = 5$ and $t = 4$, the algebraic set is not a compete intersection. (Received September 16, 2013)

1096-13-1657 **Olgur Celikbas*** (celikbaso@missouri.edu), University of Missouri, Columbia, MO 65211, and **Greg Piepmeyer**. *Syzygies and tensor product of modules.*

If R is a local hypersurface (a commutative Noetherian ring that is a complete intersection of codimension one) and M and N are nonzero finitely generated R-modules such that either M or N has a rank, and $M \otimes_R N$ is a second syzygy module, then a remarkable theorem of Huneke and Wiegand (referred as the second rigidity theorem) states that the pair (M, N) is Tor-independent, and this implies that both M and N are first syzygy modules.

In this talk I will discuss my joint work with Greg Piepmeyer that obtains a partial generalization of the second rigidity theorem over complete intersections of arbitrary codimension:

Let R be a local complete intersection of codimension c and let M and N be nonzero finitely generated R-modules. Assume $M \otimes_R N$ is an $(n + c)$th syzygy module for some nonnegative integer n. Assume further that the pair (M, N) is Tor-independent. Then both M and N are nth syzygy modules.

I will also discuss some recent related results and open questions that come from our work. (Received September 16, 2013)

1096-13-1663 **Pye Phyo Aung*** (pye.aung@ndsu.edu). *Gorenstein Dimensions, Amalgamated Duplication of a Ring, and Pseudocanonical Covers.*

When E is a semidualizing module over a commutative ring, Holm and Jørgensen studied some connections between E-Gorenstein injective/projective/flat dimensions and Nagata's trivial extension $R \ltimes E$. We generalize these results to other general constructions including D'Anna and Fontana's amalgamated duplication $R \bowtie E$ of a ring along an ideal and Enescu's pseudocanonical covers $S(f)$. We also identify some key properties of those general constructions that give similar connections to Gorenstein injectivity, projectivity and flatness. (Received September 16, 2013)

1096-13-1694 **Robert G. Underwood*** (runderwo@aum.edu), Auburn University Montgomery, Department of Mathematics, P.O. Box 244023, Montgomery, AL 36124. *Extensions of Group Schemes in Characteristic p.*

Let p be a rational prime, let $n \geq 1$ be an integer and let $\mathbb{F}_q$ denote the field with $q = p^n$ elements. Let t be an indeterminate and let $R = \mathbb{F}_q[[t]]$ and $K = \mathrm{Frac}(R) = \mathbb{F}_q((t))$. Let C_p denote the cyclic group of order p generated by g. For each integer $i \geq 0$, $H(i) = R[\frac{g-1}{t^i}]$ is an R-Hopf order in KC_p corresponding to the group scheme $\mathbb{G}_i = \mathrm{Spec}\ H(i)$. Let $i, j \geq 0$ be integers. In this talk we investigate the extensions of $\mathbb{G}_j$ by $\mathbb{G}_i$. (Received September 17, 2013)

1096-13-1711 **Sean Sather-Wagstaff** and **Richard Wicklein*** (wickleinr@morningside.edu). *Codualizing Complexes.* Preliminary report.

Let R be a commutative, noetherian ring. A finitely generated R-module C is said to be semdualizing if $\mathrm{Ext}^i_R(C, C) = 0$ for all $i > 0$ and $R \xrightarrow{\cong} \mathrm{Hom}_R(C, C)$. When R is local, an artinian R-module T is said to be quasidualizing if $\mathrm{Ext}^i_R(T, T) = 0$ for all $i > 0$ and $\widehat{R} \xrightarrow{\cong} \mathrm{Hom}_R(T, T)$. Using the notion of $\mathfrak{a}$-cofiniteness, we introduce a unifying notion that recovers each of the above notions as special cases. We then discuss the translation of the property to the setting of complexes and examine the Auslander and Bass classes in the this setting. (Received September 16, 2013)

1096-13-1744 **Bhargav Bhatt***, Einstein Drive, Princeton, NJ 08540. *A finiteness theorem in local cohomology.*

I will discuss joint work with Manuel Blickle, Gennady Lyubeznik, Anurag K. Singh, and Wenliang Zhang on the resolution of a special case of Lyubeznik's conjecture on the finiteness for local cohomology modules of all regular rings. (Received September 16, 2013)

1096-13-1755 **Lacey Johnson*** (johns4la@dukes.jmu.edu), 1419 Aquia Drive, Stafford, VA 22554, and **Elizabeth Arnold**. *K-potent Groebner bases and Sudoku.* Preliminary report.

Sudoku can be described as a system of polynomials which can then be solved using Groebner basis techniques. A Boolean idempotent approach ($x^2 = x$) restricts degree growth of intermediate polynomials, but increases the number of variables. We use a k-potent approach ($x^k = x$) allowing each variable to take on k values. The approach restricts degree growth, but minimizes the number of variables. Preliminary results show the k-potent approach produces the fastest results. (Received September 16, 2013)

1096-13-1763 **Linquan Ma*** (lquanma@umich.edu), 610 Hidden Valley Club Dr, Apt 216, Ann Arbor, MI 48104. *F-injectivity and Buchsbaum singularities.* Preliminary report.

Let (R, m) be a local ring of equal characteristic p¿0. We show that when $H^i_m(R)$ has finite length for all $i < \dim R$, R is F-injective if and only if every ideal generated by a system of parameters is Frobenius closed. As a corollary, we answer a question of Takagi that F-injective singularities with isolated non-Cohen-Macaulay locus are Buchsbaum. We also prove that, in characteristic 0, Du Bois singularities with isolated non-Cohen-Macaulay locus are Buchsbaum in the standard graded case. (Received September 16, 2013)

1096-13-1829 **Kristen A Beck*** (kbeck@math.arizona.edu) and **Sean Sather-Wagstaff**. *Systems of parameters for complexes.*

In this talk, we will investigate the notion of a system of parameters for a homologically finite complex over a commutative noetherian local ring. Specifically, we will compare our notion, defined in terms of length, to one defined by Christensen in terms of minimal primes. While these notions differ in general, we will show that they agree when the complex admits the structure of a DG algebra. (Received September 16, 2013)

1096-13-1831 **Branden Stone*** (bstone@bard.edu), **Courtney Gibbons**, **Jack Jeffries**, **Sarah Mayes**, **Claudiu Raicu** and **Bryan White**. *Non-simplicial decompositions of Betti diagrams of complete intersections.*

The theory of Boij and Söderberg allows us to decompose Betti diagrams into pure diagrams. In this talk we relax the requirement that the degree sequences in such pure diagrams be totally ordered. As a result, we were able to define a multiplication law for Betti diagrams that respects the decomposition. Given the Betti diagram of any complete intersection, this new law allows us to write a simple pure diagram decomposition in terms of the degrees of the minimal generators for the complete intersection. This work was done as part of a Mathematical Sciences Research Institute summer graduate workshop in 2011. (Received September 16, 2013)

1096-13-1866 **Hailong Dao** and **Ilya Smirnov*** (is6eu@virginia.edu). *A generalization of Hilbert-Kunz multiplicity.*

Let $(R, \mathfrak{m})$ be a local ring of characteristic $p > 0$ and M a finitely generated R-module. We study the existence of the limit: $\lim\limits_{n\to\infty} \frac{\ell(\mathrm{H}^0_{\mathfrak{m}}(F^n(M)))}{p^{n \dim R}}$ where $F(-)$ is the Peskine-Szpiro functor.

We prove that, if R is a complete intersection isolated singularity, then the limit is 0 if and only if the projective dimension of M is less than the Krull dimension of R. As a consequence, we show that Frobenius is asymptotically rigid. (Received September 16, 2013)

1096-13-1935 **Bernadette Boyle*** (boyleb7@sacredheart.edu), Sacred Heart University, 5151 Park Ave, Fairfield, CT 06825. *The Unimodality of Pure O-Sequences of Type Three in Three Variables.*

Since the 1970's, great interest has been taken in the study of pure O-sequences, which are in bijective correspondence to the Hilbert functions of Artinian level monomial algebras. Much progress has been made in classifying these by their shape. It has been shown that all monomial complete intersections, Artinian algebras in two variables and Artinian level monomial algebras with type two in both three and four variables have unimodal Hilbert functions. In this talk, we will show that Artinian level monomial algebras of type three in three variables have unimodal Hilbert functions. (Received September 17, 2013)

1096-13-2247 **Nicolas Allen Smoot*** (ns0566@stu.armstrong.edu), 114 Blue Heron Court, Richmond Hill, GA 31324. *On the Stability of Ring Structures in Direct Limits.* Preliminary report.

In this talk all rings are commutative with 1. It is known that the direct limit of a directed partially-ordered set of rings (domains) and ring homomorphisms is itself a ring (domain). We wish to consider these types of direct limit constructions. In particular, we will be interested in determining whether a property which is shared by every ring in a directed partially-ordered set is necessarily preserved in the direct limit. (Received September 17, 2013)

1096-13-2385 **Christopher Park Mooney*** (cpmooney@viterbo.edu), 900 Viterbo Dr, Reinhart Center, Viterbo University, La Crosse, WI 54601. *On a connection between commutative rings and graphs.*

In this talk, I present research from a paper due to appear studying generalized irreducible divisor graphs. This research comes out of a fruitful program initiated by Istvan Beck (1988) in which the author studied the relationship between a commutative ring and an associated zero-divisor graph. This connection between graph theory and algebra has become quite popular recently. It has been further advanced by studying co-maximal graphs and irreducible divisor graphs. These graphs have given much insight into other characterizations of various finite factorization properties.

This paper, uses advances in generalized factorization theory, in particular τ-factorization, to exploit the connection between associated graphs and τ-finite factorization properties of commutative rings. (Received September 17, 2013)

1096-13-2388 **Sara L. C. Malec*** (smalec@pacific.edu), Department of Mathematics, University of the Pacific, Stockton, CA 95207. *On the Intersection Algebra of Ideals.*

Given two ideals in a Noetherian ring, the intersection algebra is an object that captures some information on the relationships between those two ideals. In this talk, we use a connection to semigroup rings to describe many properties of the intersection algebra of ideals in a UFD, including an algorithm that produces its generating set. (Received September 17, 2013)

1096-13-2532 **Paul Baginski*** (pbaginski@fairfield.edu), Department of Mathematics and Computer Scienc, 1073 North Benson Rd., Fairfield, CT 06824, and **George T Schaeffer**. *Length multiset-complete Krull monoids.*

Let H be a Krull monoid or Krull domain, let G be its divisor class group, and let $G_0 \subset G$ be the classes containing prime divisors. It is well known that each nonunit $x \in H$ has only finitely many factorizations into irreducibles. If $x = a_1 \cdots a_n$ is a factorization $\mathbf{z}$ of x into irreducibles, the length of this factorization is $n = |\mathbf{z}|$. We elaborate upon the well-studied set $\mathcal{L}(x)$ of factorization lengths of x to account for the number of factorizations of a given length. If $Z(x)$ is the set of factorizations of x (a subset of the free monoid over the irreducibles of H), then the length multiset of x, denote $\mathcal{LM}(x)$, is the multiset $\{\{\ |\mathbf{z}|\ :\ \mathbf{z} \in Z(x)\,\}\}$.

Kainrath has shown that if the Krull monoid H has infinite class group G and $G_0 = G$, then for any finite multiset S on $\mathbb{N}\backslash\{1\}$, there is an $x \in H$ with $\mathcal{LM}(x) = S$. Kainrath's proof was nonconstructive. In this talk we will give the background on Kainrath's result and illustrate a constructive proof for $G = \mathbb{Z}$. We will also discuss recent work to extending Kainrath's result to Krull monoids with $G = \mathbb{Z}$ but G_0 a proper subset of $\mathbb{Z}$. (Received September 17, 2013)

1096-13-2611 **Taryn Laird*** (tml94@nau.edu). *Trees of Irreducible Numerical Semigroups.*

A 2011 paper by Blanco and Rosales describes an algorithm for constructing a directed tree graph of irreducible numerical semigroups with fixed Frobenius numbers. We will explain the algorithm, construct examples, present new findings, and state several conjectures about these directed tree graphs. (Received September 17, 2013)

1096-13-2637 **Bryan C White*** (bcwhite64@gmail.com). *Computational investigation of star operations with Macaulay 2.*

We investigate the actions of star operation of the form $J^\star = (I : (I : J))$ for some fixed fractional ideal I on numerical semigroup rings using the computer program Macaulay 2. We do this by representing our numerical semigroup ring as a quotient of a polynomial ring in several variables and then applying the colon function in Macaulay. We also find limitations on possible actions of arbitrary star operations using the fact that if a fractional ideal A is $\star$-closed, then so is $(A : B)$ for any fractional ideal B. (Received September 17, 2013)

1096-13-2724 **Ashwini Bhat**, **Jennifer Biermann*** (jbierman@mtholyoke.edu) and **Adam Van Tuyl**. *Generalized cover ideals and the persistence property.*

Let I be a square-free monomial ideal in $R = k[x_1, \ldots, x_n]$, and consider the sets of associated primes $\mathrm{Ass}(I^s)$ for all integers $s \geq 1$. We introduce a family of square-free monomial ideals that can be associated to a finite simple graph G that generalizes the cover ideal construction. When G is a tree, we show our ideals satisfy the persistence property. We also describe the elements of $\mathrm{Ass}(I^s)$ and explicitly determine the index of stability. (Received September 18, 2013)

14 ► Algebraic geometry

1096-14-75 **Mihai Fulger*** (afulger@princeton.edu), **Brian Lehmann**, **Xiaolei Zhao** and **Zhixian Zhu**. *Pseudo-effective numerical classes with vanishing pushforward.*

In a recent paper, Debarre, Jiang, and Voisin propose a series of conjectures that state that the vanishing of a limit of effective (co)homological classes via a push-forward map should be visible geometrically.

We are interested in the numerical version of this statement. For an arbitrary projective variety over an algebraically closed field K, the pseudo-effective cone $Eff_k(X)$ is the closure of the cone of classes of effective cycles of dimension k in the numerical group $N_k(X)$ with real coefficients.

If $\pi : Y \to X$ is a morphism of projective varieties and $\alpha \in Eff_k(Y)$ satisfies $\pi_*\alpha = 0$, the conjecture is that α is a limit of classes of effective cycles that are contracted by π to cycles of smaller dimension. A weaker form of the conjecture states that α is a linear combination with possibly negative coefficients of classes of effective contracted cycles.

We prove the strong form of the conjecture for divisors, curves, and when π is a birational morphism of four-folds. This generalizes and extends the results of Debarre, Jiang, and Voisin.

We also prove the weak form of the conjecture for vector bundle maps, and for birational morphisms over a complex projective manifold. (Received July 12, 2013)

1096-14-190 **Alberto Chiecchio*** (chieca@math.washington.edu) and **Stefano Urbinati** (stefano.urbinati@unipd.it). *Positivity for Weil divisors.*

In "Singularities on normal varieties" de Fernex and Hacon defined the birational pullback of Weil divisors, making Weil divisors a more feasible tool for studying non-$\mathbb{Q}$-Gorenstein singularities, especially (but not exclusively) in the context of the MMP. This led to more recent works of Bouksom, de Fernex, Favre, and the authors. Trying to extend this idea, we define positivity for Weil divisors. Joint with S. Urbinati (Received August 15, 2013)

1096-14-247 **Youngmi Hur**, 100 Whitehead Hall, 3400 North Charles St., Baltimore, MD 21210, and **Fang Zheng***, 100 Whitehead Hall, 3400 North Charles St., Baltimore, MD. *The Design of Non-redundant Directional Wavelet Filter Bank Using* 1*-D Neville Filters.* Preliminary report.

In this paper, we develop a method to construct non-redundant directional wavelet filter banks. Our method uses a special class of filters called Neville filters and can construct non-redundant wavelet filter banks in any dimension for any dilation matrix. The resulting filter banks have directional analysis highpass filters, thus can be used in extracting directional contents in multi-D signals such as images. Furthermore, one can custom-design the directions of highpass filters in the filter banks. (Received August 22, 2013)

1096-14-263 **Andrew Obus***, 141 Cabell Drive, Kerchof Hall, Charlottesville, VA 22904. *Toward a generalization of the Oort conjecture.*

The Oort conjecture (proven by joint work of the speaker, Stefan Wewers, and Florian Pop) states that any G-Galois branched cover of smooth projective curves can be lifted from characteristic p to characteristic zero, as long as G is cyclic. We call a finite group with the above lifting property an *Oort group* (so cyclic groups are Oort groups). If G is instead a group of the form $\mathbb{Z}/p^n \rtimes \mathbb{Z}/m$ with $p \nmid m$ and $m > 1$, then not every G-Galois branched cover lifts to characteristic zero, and there is a known obstruction to lifting called the *Bertin obstruction*. I conjecture that the Bertin obstruction is the only obstruction in this case. From this, it would follow that the dihedral groups of order $2p^n$ for odd p are Oort groups for every n (this is known for $n = 1$, by work of Irene Bouw and Stefan Wewers). We present progress toward this more general conjecture, including the first explicit known examples of liftable G-covers where G is dihedral of order $2p^n$, $p > 2$, $n \geq 2$, and the cover has a totally ramified point. (Received August 24, 2013)

1096-14-370 **Lindsay Erickson*** (lindsay@math.washington.edu). *Rational Pairs: Motivation and Results.* Preliminary report.

I will first discuss János Kollár and Sándor Kovács's recent work defining rational singularities for pairs (X, D), where X is a normal variety and D is a reduced divisor. Then I'll introduce some new work towards understanding these singularities of pairs. In 1978 Renée Elkik proved that rational singularities of varieties are in some sense deformation invariant: given a flat family of varieties, if a fiber over a smooth point has rational singularities, then the nearby fibers do too. I will present an analogue of this theorem for rational pairs. (Received August 30, 2013)

1096-14-400 **Michele Torielli*** (torielli@math.sci.hokudai.ac.jp), Kita 10, Nishi 8, Kita-Ku, Sapporo, Hokkaido 060-0810, Japan, and **Masahiko Yoshinaga** and **Shaheen Nazir**. *On the admissibility of certain local systems.*

A rank one local system $\mathcal{L} \in \mathbb{T}(M)$ on a smooth complex algebraic variety M is admissible roughly speaking if the dimension of the cohomology groups $H^m(M, \mathcal{L})$ can be computed directly from the cohomology algebra $H^*(M, \mathbb{C})$. In this talk we will describe the relations between admissible local systems and points of the characteristic variety of the given arrangement. (Received September 02, 2013)

1096-14-450 **Tyler Foster**, **Joseph Rabinoff**, **Farbod Shokrieh*** (farbod@math.cornell.edu) and **Alejandro Soto**. *Faithful Tropicalization of Abelian Varieties.*

I will describe the ongoing joint work with Tyler Foster, Joe Rabinoff, and Alejandro Soto, where we study faithful tropicalization of abelian varieties. For an abelian variety, the skeleton (in the sense of Berkovich) is a real torus with an "integral structure". For totally degenerate Jacobians, we give an explicit faithful tropicalization in terms of p-adic and tropical theta functions. The solution relies on interesting combinatorial facts about lattices and Voronoi decompositions. (Received September 17, 2013)

1096-14-457 **Qingchun Ren**, **Kristin Shaw** and **Bernd Sturmfels*** (bernd@berkeley.edu), Department of Mathematics, University of California, Berkeley, CA. *Tropical Del Pezzo Surfaces.* Preliminary report.

Del Pezzo surfaces are obtained by blowing up the plane at few points. We explore this tropically for five and six points, with the goal of drawing pictures of the intrinsic tropicalization of a cubic surface minus its 27 lines. Our techniques range from controlled modifications to running gfan on the universal Cox ideal over the relevant moduli space. (Received September 03, 2013)

1096-14-644 **Maxim V Arap*** (marap@math.jhu.edu), Johns Hopkins University, Department of Mathematics, 404 Krieger Hall, 3400 N. Charles Street, Baltimore, MD 21218. *On Betti numbers of tautological rings of Jacobians and Pryms.* Preliminary report.

This talk will be a report of the joint work with David Swinarski on a conjecture regarding the Betti numbers of tautological rings of Jacobians and its extension to Pryms. (Received September 08, 2013)

1096-14-666 **Claudiu Raicu*** (craicu@math.princeton.edu) and **Jerzy Weyman**. *Local cohomology with support in generic determinantal ideals.*

The space $Mat(m,n)$ of $m \times n$ matrices admits a natural action of the group $\mathrm{GL}_m \times \mathrm{GL}_n$ via row and column operations on the matrix entries. The invariant closed subsets are the closures of the orbits of constant rank matrices. I will explain how to describe the local cohomology modules of the ring S of polynomial functions on $Mat(m,n)$ with support in these orbit closures, and mention some consequences of the methods employed to computing minimal free resolutions of invariant ideals in S. These ideals correspond to nilpotent scheme structures on the orbit closures, and their study goes back to the work of De Concini, Eisenbud and Procesi in the 80s. (Received September 09, 2013)

1096-14-686 **Rostam Sabeti*** (rsabeti@olivetcollege.edu), Department of Mathematics, Olivet College, Olivet, MI 49076. *Scheme of cyclic-9; A numerical-symbolic approach.*

Let $A := \mathbb{C}[x_1, \cdots, c_9]$. In 2001, Jean-Charles Faugère determined the solution set of cyclic-9, by computer algebra methods and Gröbner basis computation. In this talk, to derive the exact form of defining polynomials of 6 prime ideals of dimension 2 in primary decomposition of cyclic-9 a new symbolic-numerical algorithm will be presented. For a typical ideal of cyclic-9 of dimension 2, i.e., $\mathfrak{p} = \langle x_1 + \omega x_7, x_2 + \omega x_8, x_3 + \omega x_9, x_4 + \bar{\omega} x_7, x_5 + \bar{\omega} x_8, x_6 + \bar{\omega} x_9, x_7 x_8 x_9 + \omega \rangle$ $(\omega := \frac{1}{2} - \frac{\sqrt{3}i}{2})$, we present a proof of primality and the structure of its residue class field as

$$((A \backslash \mathfrak{p})/\mathfrak{p})^{-1}(A/\mathfrak{p}) = \left\{ \frac{f}{g} : f, g \in \bigoplus_{i=7}^{9} x_i \mathbb{C}[x_i] \oplus \eta \mathbb{C}[x_7, x_8] \oplus \delta \mathbb{C}[x_8, x_9] \oplus \sigma \mathbb{C}[x_7, x_9] \oplus \mathbb{C}; g \neq 0 \right\},$$

where $\eta := x_7 x_8$, $\delta := x_8 x_9$, $\sigma := x_7 x_9$. (Received September 09, 2013)

1096-14-691 **Gabriele Di Cerbo***, Department of Mathematics, 2990 Broadway, Room 509, New York, NY 10027. *Effective results for toroidal compactifications.*

The goal of this talk is to study the geometry of cusped complex hyperbolic manifolds through their compactifications. First, we characterize toroidal compactifications with non-nef canonical divisor. Surprisingly, they admit only very simple extremal contractions. A detailed study of their extremal rays will allow us to derive effective very ampleness results for toroidal compactifications of finite volume complex hyperbolic manifolds and to give effective bounds on the number of complex hyperbolic manifolds with given upper bounds on the volume. Moreover, we will estimate the number of ends of such manifolds in terms of their volume. Many of the statements in the case of surfaces are essentially sharp. (Received September 09, 2013)

1096-14-722 **Charles W. Wampler*** (charles.w.wampler@gm.com), General Motors R&D, Mail Stop 480-106-224, 30500 Mound Road, Warren, MI 48090-9055. *Applications of Numerical Real Algebraic Geometry to Kinematics.* Preliminary report.

Recently, numerical algorithms have been developed for computing cell decompositions of the real points in complex algebraic curves and surfaces. These algorithms operate in the spirit of Morse theory by introducing a real projection and using numerical algebraic geometry to find the critical sets where the topology of the real fibers of the projection change. After slicing the set between critical points to get the generic behavior in each interval, one uses continuation to the critical points to determine how the pieces glue together to make the whole set. After a brief review of the state of the art in this approach, we will concentrate on how these methods apply to several examples from the kinematics of mechanism design and robot control. (Received September 09, 2013)

1096-14-736 **Timothy Leake** and **Dhruv Ranganathan*** (dhruv.ranganathan@yale.edu).
Brill–Noether Theory of Maximally Symmetric Graphs.

In this talk I will discuss joint work with Timothy Leake, in which we analyze the Brill–Noether theory of trivalent graphs and multigraphs having largest possible automorphism group. We exhibit Brill–Noether special graphs in any sufficiently large genus, yielding counterexamples to a conjecture of Caporaso. (Received September 09, 2013)

1096-14-740 **Florian Block*** (block@math.berkeley.edu), UC Berkeley, and **Lothar Göttsche** (gottsche@ictp.it), International Centre for Theoretical Physics, Trieste, Italy. *Fock Space, Feynman Diagrams, Floor Diagrams, and (Refined) Severi Degrees.*

We compute the degree of the Severi variety by considering the action of a non-commutative (Heisenberg) algebra on its Fock space. This results in a combinatorial computation of the Severi degree in terms of Feynman diagrams. These diagrams are essentially the floor diagrams arising in tropical geometry. (Received September 09, 2013)

1096-14-820 **Christopher D. Hacon*** (hacon@math.utah.edu), Salt Lake City, UT 84112. *On generic vanishing in characteristic p>0.*

We will discuss a generalization of generic vanishing to characteristic p $>$ 0 and the failure of the traditional generic vanishing in characteristic p $>$ 0. (Received September 10, 2013)

1096-14-890 **Mounir Nisse*** (mounir.nisse@gmail.com), Max Planck Institute for Mathematics, Vivatsgasse 7, 53111 Bonn, Bonn, Germany, and **Frank Sottile** (sottile@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77843-3368.
Arrangement of tori and the topology of coamoebas complement of algebraic varieties.

Amoebas (resp. coamoebas) are the image under the logarithmic (resp. argument) map of algebraic (or analytic)varieties of the complex algebraic torus. they inherit some algebraic, geometric, and topological properties of the variety itself. First, in the hypersurfaces case, we define a subset of the real torus called the *shell* of the coamoeba, with boundary contained in an arrangement of codimension one tori. Then, we show that the number of complement components of a coamoeba is bounded by the number of complement components of its shell. More precisely, we prove the following:

$$\#\{(S^1)^n \setminus \overline{co\mathcal{A}(V)}\} \leq \#\{(S^1)^n \setminus \mathcal{H}(V)\} \leq n!\mathrm{Vol}(\Delta),$$

where Δ is the Newton polytope of the defining polynomial of the hypersurface V. If the codimension k is greater than one, then we show that the coamoeba contains an arrangement of $(n-k)$-dimensional tori which has some algebraic, geometric, and topological properties inherited from the original variety itself. (Received September 11, 2013)

1096-14-927 **Lubjana Beshaj*** (beshaj@oakland.edu). *Genus 3 algebraic curves.*

We describe some of the basic properties of genus 3 algebraic curves, their invariants, automorphism groups, the stratification of the moduli space $\mathcal{M}_3$, and rational models of curves over their field of moduli (Received September 11, 2013)

1096-14-955 **Christopher D. Hacon***, 155 S 1400 E Room 233, Salt Lake City, UT 84112. *Which Powers of a Holomorphic Function are Integrable?*

Let $f = f(z_1, \dots, z_n)$ be a holomorphic function defined on an open subset $P \in U \subset \mathbb{C}^n$. The log canonical threshold of f at P is the largest $s \in \mathbb{R}$ such that $|f|^{-s}$ is locally integrable at P. This invariant gives a sophisticated measure of the singularities of the set defined by the zero locus of f which is of importance in a variety of contexts (such as the minimal model program and the existence of Kähler-Einstein metrics in the negatively curved case). In this talk we will discuss recent results on the remarkable structure enjoyed by these invariants. (Received September 11, 2013)

1096-14-972 **Zsolt Patakfalvi**, Department of Mathematics, Princeton University, Princeton, NJ, **Karl Schwede*** (schwede@math.psu.edu), Department of Mathematics, Penn State University, University Park, PA 16802, and **Wenliang Zhang**, Department of Mathematics, University of Nebraska, Lincoln, NE. *F-singularities in families.*

F-singularities are classes of singularities defined by the behavior Frobenius. A prominent tool for measuring these singularities is the test ideal, a characteristic p > 0 analog of the multiplier ideal. Recently, there has been interest in applying the methods of F-singularities to a number of geometric problems in positive characteristic. However, one gap in the theory has been the behavior of F-singularities in families. For example restriction theorems for test ideals have been lacking. In this talk, I will discuss recent joint work with Zsolt Patakfalvi and Wenliang Zhang on the behavior of F-singularities and test ideals in families. For example, we will obtain generic (and non-generic) restrictions theorems for test ideals. Some global geometric consequences will also be discussed if there is sufficient time. (Received September 11, 2013)

1096-14-993 **Ralph E Morrison*** (r.elliottmaelstrom@gmail.com), Department of Mathematics, University of California, Berkeley, 970 Evans Hall, Berkeley, CA 94704, and **Qingchun Ren**. *Algorithms for Mumford Curves: Good Starting Data.*

Mumford curves are curves over non-Archimedean fields that arise from certain groups, called Schottky groups, acting on the field. To specify a Mumford curve, it suffices to give generators for the corresponding Schottky group. However, starting out with extra data for the curve can make many otherwise inefficient or even impossible calculations doable. We will show how to find "good" generators for Schottky groups to make algorithms more efficient, and how hyperelliptic Mumford curves (arising from Whittaker groups) become more computationally understandable when presented in the right way. (Received September 12, 2013)

1096-14-1033 **Douglas A. Torrance*** (dtorrance@monmouthcollege.edu) and **Zach Teitler** (zteitler@boisestate.edu). *Properties of complete bipartite codimension two subspace arrangements.*

Consider an arrangement of codimension two linear subspaces in projective space. Any two distinct subspaces in this arrangement will intersect in codimension three or four. We may therefore define the incidence graph of such an arrangement. The vertices of the incidence graph are the subspaces in the arrangement, and two vertices are adjacent if and only if the corresponding subspaces intersect in codimension three.

We investigate the properties of arrangements whose incidence graphs are complete bipartite graphs. In particular, we can determine the Castelnuovo-Mumford regularity and arithmetic Cohen-Macaulayness of the arrangement from the cardinality of the partite sets. (Received September 12, 2013)

1096-14-1040 **Andrew Sommese*** (sommese@nd.edu), Dept. of Appl. & Comp. Math & Stats., University of Notre Dame, Notre Dame, IN 46556. *Numerical algebraic geometry over number fields.*

I will present some work of Wenrui Hao, Chris Peterson, and myself on how to recover exact information about an algebraic set defined over a number field from the output of the adaptive precision algorithyms of numerical algebraic geometry. (Received September 12, 2013)

1096-14-1047 **Nero Budur*** (nero.budur@wis.kuleuven.be). *Cohomology support loci and Bernstein-Sato ideals.*

Cohomology support loci of rank one local systems on complements of hyperplane arrangements are easy to calculate. Examples show that the equations these loci come from the so-called Bernstein-Sato ideals. This motivates a conjecture we make in general, beyond the hyperplane arrangement case, relating cohomology support loci with Bernstein-Sato polynomials. We prove half of this conjecture. This conjecture should be the right generalization to the case of many polynomials of the result of Malgrange and Kashiwara relating, in the one polynomial case, the eigenvalues of the monodromy on Milnor fibers with the roots of the classical Bernstein-Sato polynomial. (Received September 12, 2013)

1096-14-1175 **Harry Tamvakis***, University of Maryland, 1301 Mathematics Building, College Park, MD 20742. *Schubert calculus on isotropic Grassmannians.*

We will discuss combinatorial aspects of the structure of the cohomology ring of isotropic Grassmannians, in its natural geometric basis of Schubert classes. This uses the classical raising operators of A. Young and D. Littlewood, and a new calculus of these operators which was found in joint work with Anders Buch and Andrew Kresch. (Received September 13, 2013)

1096-14-1200 **Hal Schenck*** (schenck@math.uiuc.edu), Math Department, University of Illinois, 1409 W. Green St, Urbana, IL 61801, and **Hiroaki Terao** and **Masahiko Yoshinaga**.
Logarithmic vector fields and curve configurations in the projective plane.

Let $\mathcal{A} = \bigcup_{i=1}^{r} C_i \subseteq \mathbb{P}^2$ be a collection of smooth plane curves, such that each singular point is quasihomogeneous. We prove that if C is a smooth curve such that each singular point of $\mathcal{A} \cup C$ is also quasihomogeneous, then there is an elementary modification of rank two bundles,which relates the $\mathcal{O}_{\mathbb{P}^2}$–module $Der(log\mathcal{A})$ of vector fields on $\mathbb{P}^2$ tangent to $\mathcal{A}$ to the module $Der(log\mathcal{A} \cup C)$. This yields an inductive tool for studying the splitting of the bundles $Der(log\mathcal{A})$ and $Der(log\mathcal{A} \cup C)$, depending on the geometry of the divisor $\mathcal{A}|_C$ on C. (Received September 13, 2013)

1096-14-1223 **Ellen J. Goldstein*** (ellen.goldstein@bc.edu), Department of Mathematics, Carney Hall, Room 301, Boston College, Chestnut Hill, MA 02467. *Using a Generalization of Young Diagrams to Study a Normality Problem.*

Question: When are closures of conjugacy classes of nilpotent elements in the symplectic and orthogonal Lie algebras normal? Young diagrams are an obvious tool for studying this problem since they provide a succinct description of the conjugacy classes. However, we can use a particular generalization of Young diagrams, called ab-diagrams, to unify the symplectic and orthogonal cases into one "orthosymplectic" case. Through ab-diagrams, we can find an explicit formula for the dimension of these orthosymplectic orbits, which we can use to study singularities in the original closures. (Received September 13, 2013)

1096-14-1272 **Matt Baker*** (mbaker@math.gatech.edu) and **Joe Rabinoff**. *The skeleton of the Jacobian, the Jacobian of the skeleton, and lifting meromorphic functions from tropical to algebraic curves.*

Given a smooth, proper, connected curve X over a non-Archimedean field and a skeleton Γ of the Berkovich analytification X^{an}, there are two natural real tori which one can consider: the tropical Jacobian $\mathrm{Jac}(\Gamma)$ and the skeleton of the Berkovich analytification $\mathrm{Jac}(X)^{\mathrm{an}}$. We show that the skeleton of the Jacobian is canonically isomorphic to the Jacobian of the skeleton as principally polarized tropical abelian varieties. As a consequence, we determine exactly which principal divisors on Γ, in the sense of tropical geometry, are the retractions of principal divisors on X. We use this to prove that there is a rational map $f : X \dashrightarrow \mathbf{P}^3$ whose tropicalization, when restricted to Γ, is an isometry onto its image. (Received September 14, 2013)

1096-14-1374 **Alexandra Seceleanu*** (aseceleanu@unl.edu) and **Brian Harbourne**. *Regular versus symbolic powers for ideals of points in positive characteristic.*

When I is the radical homogeneous ideal of a finite set of points in projective N-space, it has been conjectured by Harbourne and Huneke that the symbolic power $I^{(rN-N+1)}$ should be contained in the regular power I^r for all $r \geq 1$. A counterexample of Dumnicki, Szemberg and Tutaj-Gasinska shows that this can fail when $N = r = 2$. In this talk, we show that failures occur for infinitely many r in every characteristic $p > 2$ when $N = 2$, and we find additional positive characteristic failures when $N > 2$. (Received September 15, 2013)

1096-14-1422 **Taylor C. Brysiewicz*** (tbrysiewicz@yahoo.com), 1422 Saddleridge PL, Bartlett, IL 60103, and **Leah Balay-Wilson**. *Families of Plane Cubic Curves with Nine-Pointic Contact at a Point.*

For any point on a plane cubic curve, it may or may not be possible to construct another cubic curve that will intersect it at that point with multiplicity nine. In this talk we provide a necessary and sufficient geometric condition for smooth points on a plane cubic curve to have this property. At such a point, we show that one can construct an infinite family of these cubics and in particular, this family is parametrized by the osculating conic at that point. (Received September 15, 2013)

1096-14-1445 **Ralph Morrison** and **Qingchun Ren*** (qingchun@berkeley.edu). *Algorithms for Mumford curves: period matrix and canonical embedding.*

Mumford showed that Schottky subgroups of $PGL(2, K)$ give rise to certain curves, now called Mumford curves, over a non-Archimedean field K. Such curves are foundational to subjects dealing with non-Archimedean curves, including Berkovich theory and tropical geometry. We develop and implement numerical algorithms for Mumford curves. Our main algorithms include: approximating the period matrices of the Jacobians of Mumford curves; computing the Berkovich skeleta of the analytifications of such curves; and approximating points in canonical embeddings. (Received September 15, 2013)

1096-14-1449 **Elham Izadi**, **CS Tamás** and **Jie Wang*** (jiewang@math.uga.edu), Department of Mathemetics, University of Georgia, Athens, GA 30602. *The primitive cohomology of the theta divisor of an abelian fivefold.*

The primitive cohomology of the theta divisor of a principally polarized abelian variety of dimension g is a Hodge structure of level $g-3$. The Hodge conjecture predicts that it is contained in the image, under the Abel-Jacobi map, of the cohomology of a family of curves in the theta divisor. In this talk, I will explain how one can use the Prym map to show that this version of the Hodge conjecture is true for the theta divisor of a general abelian fivefold. (Received September 15, 2013)

1096-14-1466 **Xiaoyan Hu*** (xhu@math.uga.edu), Department of Mathematics, University of Georgia, Athens, GA 30602. *The compactification of moduli space of Burniat surfaces with* $2 \leq K^2 \leq 5$.

Burniat surfaces are a very special case of surfaces of general type with $q = p_g = 0$. I will describe their geometry, degenerations and a compactification of moduli space of Burniat surfaces with $2 \leq K_X^2 \leq 5$ by adding slc surfaces X with ample K_X. (Received September 15, 2013)

1096-14-1486 **Madhusudan Manjunath*** (mmanjunath3@math.gatech.edu), 686 Cherry Street School of Mathematics, Atlanta, GA , and **Luo Ye**. *Smoothing of limit g_d^1s on metrized complexes.* Preliminary report.

The notion of limit linear series on curves of compact type (reducible curves whose dual graph is a tree) introduced by Eisenbud and Harris has recently been generalized to metrized complexes of curves by Amini and Baker. Eisenbud and Harris showed that any limit g_d^1 on a curve of compact type can be smoothed to a g_d^1 on a smooth curve. We study the question of smoothing a limit g_d^1 on a metrized complex. We start with an example of a limit g_d^1 on a metrized complex that cannot be smoothed. We provide an effective characterization of a smoothable limit g_d^1 on a metrized complex and examples demonstrating this characterization. This is work in progress with Luo Ye. (Received September 15, 2013)

1096-14-1520 **Mohammed Daher*** (mohammed.daher79@yahoo.com), , New Zealand, and **Peter Donelan** (peter.donelan@vuw.ac.nz), , New Zealand. *Dual numbers and invariant theory of the Euclidean group.*

In this talk we discuss properties of the special Euclidean group SE(3) from two points of view, algebraic and geometric. From the algebraic point of view we introduce a dualization procedure for the special orthogonal group SO(3) vector invariants and obtain vector invariants of the adjoint action of SE(3) acting on multiple screws. In the case of three screws, there are 14 basic invariants related by two basic syzygies. Moreover, we show that any invariant of the same group under the same action can be expressed as a rational function evaluated on those 14 vector invariants.

From the geometric point of view, we study the Denavit-Hartenberg parameters which describe serial robot arms, and we calculate formulae for link-lengths and offsets in terms of vector invariants of the adjoint action of SE(3). Moreover, we obtain a geometrical duality between the offsets and the link lengths, where the geometrical dual of an offset is a link length and vice versa. (Received September 16, 2013)

1096-14-1523 **Jose Luis Gonzalez*** (jgonza@math.ubc.ca), University of British Columbia, and **Kalle Karu** (karu@math.ubc.ca), University of British Columbia. *Bivariant Equivariant Cobordism.*

We define operational versions of algebraic cobordism and equivariant algebraic cobordism. More generally, we associate a bivariant theory to any oriented Borel-Moore homology theory with intersection products. This bivariant theory has the expected features from the case of Chow cohomology. Some of our technical results include Kimura and Gillet type exact sequences for algebraic cobordism and bivariant (equivariant) cobordism. Moreover, when this sequences hold, the equivariant bivariant theory can also be computed as a suitable inverse limit, once again in analogy to the equivariant Chow cohomology case. As an example, we describe the operational equivariant cobordism of arbitrary toric varieties. (Received September 16, 2013)

1096-14-1541 **Sarah B Lobb*** (sarah.lobb@sydney.edu.au), School of Mathematics and Statistics, Carslaw Building (F07), University of Sydney, Sydney, NSW 2038, Australia. *Initial value space of integrable lattice systems and discrete Painlevé equations.*

In order to study solutions of discrete integrable systems it is desirable to have a geometric understanding of the space of initial values. We will provide an explicit construction of these spaces for simple examples, to illustrate the dynamics. (Received September 16, 2013)

1096-14-1561 **Sam Payne***, Department of Mathematics, 10 Hillhouse Ave, 442 Dunham Laboratory, New Haven, CT 06511. *Tropical Brill-Noether theory.*

I will discuss recent progress in tropical Brill-Noether theory, both on the purely combinatorial side and also in relation to applications to linear series on algebraic curves. (Received September 16, 2013)

1096-14-1689 **Eric Katz*** (eekatz@uwaterloo.ca), 200 University Avenue West, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada. *P-adic integration on algebraic curves in the bad reduction case.*

P-adic integration was introduced by Coleman in the good reduction case and extended in distinct directions by Colmez and Berkovich. We discuss a comparison theorem between the Colmez and Berkovich integrals, applications to Diophantine geometry following work of Stoll, and an algorithm for computing these integrals for hyperelliptic curves based on the work of Balakrishnan and others. This is joint work with David Zureick-Brown and possibly some others too. (Received September 16, 2013)

1096-14-1703 **Nealy Bowden**, **Yue Cao** and **Sarah Hagen***, Department of Mathematics, Smith College, Northampton, MA 01063, and **Melanie King**, **Stephanie Reinders** and **Julianna Tymoczko**. *New work on generalized splines.*

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 and Handschy-Melnick-Reinders generalized splines even further.

In this talk, we describe new work on generalized splines, with applications to representation theory and Schubert calculus. (Received September 16, 2013)

1096-14-1708 **Brian D Smithling*** (bds@math.jhu.edu), Johns Hopkins University, Department of Mathematics, 3400 N Charles St, Baltimore, MD 21218. *On the moduli description of local models for ramified unitary groups.*

Local models are schemes which are intended to model the étale-local structure of integral models of Shimura varieties. Pappas and Zhu have recently given a general group-theoretic definition of local models with parahoric level structure, valid for any tamely ramified group, but it remains an interesting problem to characterize the local models, when possible, in terms of an explicit moduli problem. In the setting of local models for ramified, quasi-split GU_n, work towards an explicit moduli description has been done by Pappas and Pappas–Rapoport. We show that the conditions they formulate are not strong enough to cut out the (flat) local model in general, and we propose a general strengthening of their moduli problem. We furthermore show that our strengthened moduli problem does characterize the local model in the case of signature $(n-1,1)$ and a certain special maximal parahoric level structure, where Pappas and Rapoport's conditions alone are not strong enough to do so. (Received September 16, 2013)

1096-14-1723 **Clifton Cunningham** and **David Roe*** (roed.math@gmail.com), 612 Campus Place N.W., Calgary, AB T2N 1N4, Canada. *A sheaf-function dictionary for algebraic tori over local fields.*

We generalize the notion of character sheaf from connected commutative algebraic groups to smooth, commutative group schemes G locally of finite type over finite fields $\mathbb{F}_q$. Assuming that the geometric component group of G is finitely-generated, we show that the group of isomorphism classes of these quasicharacter sheaves on G is canonically isomorphic to the group of characters of $G(\mathbb{F}_q)$. We use this result to exhibit an isomorphism between quasicharacters of $T(K)$ and isomorphism classes of quasicharacter sheaves on the Greenberg transform of the Néron model of T, where K is any non-archimedean local field and T is any algebraic torus over K. (Received September 16, 2013)

1096-14-1762 **Yoav Len*** (yoav.len@yale.edu), 498 Orange St., New Haven, CT 06511. *Algebraic versus combinatorial rank of divisors on graphs.*

The algebraic rank of a divisor on a finite graph is an invariant described in terms of the ranks of line bundles on all the nodal curves dual to the graph. A conjecture by L. Caporaso suggests that the algebraic rank is, in fact, equal to the combinatorial rank. In my talk, I will discuss a number of known results regarding the conjecture and some recent work on the subject. (Received September 16, 2013)

1096-14-1828 **Eric Miles*** (miles@math.colostate.edu), miles@math.colostate.edu, and **Daniele Arcara**. *Bridgeland Stability of Line Bundles on Smooth Projective Surfaces.* Preliminary report.

We introduce Bridgeland Stability Conditions and study the stability of line bundles for certain "divisorial stability conditions" defined on smooth projective surfaces. Methods of proof (including the reduction of these considerations to studying the relative geometry of conic sections in the (real) plane) and connections with representations of quivers will be discussed as time allows. (Received September 17, 2013)

1096-14-1830 **Nathan Pflueger*** (pflueger@math.harvard.edu). *Towards a tropical Castelnuovo-Severi inequality.* Preliminary report.

I will consider the question: if a tropical curve has two harmonic maps to trees of degree d and e, how large can its genus be? For the analogous question in classical algebraic geometry, the Castelnuovo-Severi inequality gives a (sharp) bound of $(d-1)(e-1)$ in the case where d and e are relatively prime. I will discuss partial results towards a tropical analog of this inequality, and discuss possible applications to the divisor theory of tropical plane curves. (Received September 16, 2013)

1096-14-1835 **Nathan Pflueger*** (pflueger@math.harvard.edu). *Exceptional linear series on curves.*

Brill-Noether theory studies the existence and deformations of curves in projective spaces; its basic object of study is $\mathcal{W}^r_{d,g}$, the moduli space of smooth genus g curves with a choice of degree d line bundle having at least $(r+1)$ independent global sections. The Brill-Noether theorem asserts that the map $\mathcal{W}^r_{d,g} \to \mathcal{M}_g$ is surjective with general fiber dimension given by the number $\rho = g-(r+1)(g-d+r)$, under the hypothesis that $0 \leq \rho \leq g$. One may naturally conjecture that for $\rho < 0$, this map is generically finite onto a subvariety of codimension $-\rho$ in $\mathcal{M}_g$. This conjecture fails in general, but seemingly only when $-\rho$ is large compared to g. I discuss a proof that this conjecture does hold for at least one irreducible component of $\mathcal{W}^r_{d,g}$, under the hypothesis that $0 < -\rho \leq \frac{r}{r+2}g - 3r + 3$. (Received September 16, 2013)

1096-14-1844 **Justin D Peachey*** (jupeachey@davidson.edu). *Applications of function fields arising from certain linearized polynomials to compressed sensing.* Preliminary report.

In 2012, Li, Gao, Ge, and Zhang constructed compressed sensing matrices from codes from the Hermitian function field. These matrices provided better parameters than previous deterministic constructions. The extended norm-trace function field $\mathbb{F}_{q^r}/\mathbb{F}_q$ is defined by

$$x^u = L(y)$$

where $L(y)$ is a separable linearized polynomial which splits over $\mathbb{F}_{q^r}$. This function field generalizes both the norm-trace function field and the Hermitian function field. Our work has yielded explicit bases for certain Riemann-Roch spaces of this function field. In this talk, we explore the applications of the resulting algebraic geometric codes to construction of compressed sensing matrices using the construction of Li, et al. We discuss when our results can yield better parameters than those previously known. (Received September 16, 2013)

1096-14-1862 **Patrick Gerald Brosnan*** (pbrosnan@umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742-4015. *Kashiwara conjugation for twisted D-modules.* Preliminary report.

Suppose X is a complex manifold. I will explain how certain rings of twisted holomorphic differential operators can be embedded in the ring of differential operators on the underlying smooth manifolds. Using this I generalize a construction of Kashiwara which gives an anti-equivalence of categories between regular holonomic D-modules on X and regular holonomic D-modules on the complex conjugate of X. This generalizes results of Barlet and Kashiwara who proved a similar result for flag varieties. (Received September 16, 2013)

1096-14-1875 **Caleb McKinley Shor*** (cshor@wne.edu), Box H-5156, Department of Mathematics, Western New England University, 1215 Wilbraham Rd, Springfield, MA 01119. *On 2-Weierstrass points of genus 3 hyperelliptic curves with extra automorphisms.*

In this talk, we focus on genus 3 hyperelliptic curves with extra automorphisms and classify their 2-Weierstrass points. Such families of curves are explicitly determined in terms of a coordinate in the hyperelliptic moduli $\mathcal{H}_3$. While our primary tool for calculating the 2-Weierstrass points is the Wronskian, we will also discuss a method to calculate q-Weierstrass points of general genus g hyperelliptic curves using Taylor polynomials. (Received September 16, 2013)

1096-14-1900 **Taisong Jing*** (taisong@math.upenn.edu), 209 S. 33rd St., David Rittenhouse Laboratory 4W1, Philadelphia, PA 19104. *Strong CM Lifting Problem.*

It is known that an abelian variety over a finite field may not admit a lifting to an abelian variety with complex multiplication in characteristic 0. In Chai, Conrad, and Oort's book *Complex Multiplication and Lifting Problems*, the question of "Strong CM Lifting" was asked: can we kill the obstructions to a CM lifting by requiring the whole ring of integers in the CM field operates on the abelian variety? This question led to the study of the closed fibers of CM abelian schemes in mixed characteristic. In this talk, I will explain how to compute the reduction of CM abelian varieties with a given CM type, using p-adic Hodge theory and Kisin modules. As a consequence, I have found counterexamples to the strong CM lifting problem, and that strong CM lifting holds under additional assumptions. Moreover, there is an example which exhibits a new phenomenon that begs for an explanation. (Received September 16, 2013)

1096-14-1961 **Joseph A Ross*** (josephr@usc.edu) and **Eric M Friedlander**. *Intersection theory on singular varieties.* Preliminary report.

We introduce some ideas from motivic cohomology into the study of singular varieties. Our approach is modeled on the intersection homology of Goresky-MacPherson; our goal is to intersect cycles on a stratified singular variety provided the cycles do not meet the strata too badly. We define "perverse" analogues of Chow groups and motivic cohomology. Properties include homotopy invariance, a localization theorem, and a splitting theorem. As a consequence we obtain pairings between certain "perverse" cycle groups on a singular variety. (Received September 16, 2013)

1096-14-1968 **Eric M. Hanson*** (hanson@math.colostate.edu), **Daniel J. Bates**, **Jonathan D. Hauenstein** and **Charles W. Wampler**. *Numerical Fiber Products for the Study of Mechanisms.*

In a family of polynomial systems depending upon parameters there is a typical dimension for the variety defined by a system in the family. However, the dimension can jump for parameters in algebraic subsets of the parameter space. With Bates, Hauenstein, and Wampler, we propose a numerical approach to identifying these special parameter values.

Our new approach is a refinement of the numerical fiber product construction of Sommese and Wampler. This talk will review the approach of Sommese and Wampler, illustrating it on a simple example and discuss the application of our new refined approach to examples from Kinematics - the study of mechanisms, such as robotic arms. (Received September 16, 2013)

1096-14-2089 **Zsolt Patakfalvi*** (pzs@princeton.edu). *On subadditivity of Kodaira dimension in positive characteristic.*

The Kodaira dimension $\kappa(X)$ is a fundamental (if not the most fundamental) birational invariant of an algebraic variety X. It is an element of $\{-\infty, 0, 1, \dots, \dim X\}$, and the bigger it is the more X is thought of as being "hyperbolic". Subadditivity of Kodaira dimension is a conjecture by Iitaka stating that for an algebraic fiber space $f\colon X \to Y$, $\kappa(X) \geq \kappa(Y) + \kappa(F)$, where F is the general fiber. I will present a positive answer to the above conjecture over a field of positive characterisitic, when $\kappa(Y) = \dim Y$, f is separable and the Hasse-Witt matrix of the geometric general fiber is not nilpotent. (Received September 17, 2013)

1096-14-2096 **Alan Koch*** (akoch@agnesscott.edu). *Kisin modules which correspond to monogenic Hopf algebras.* Preliminary report.

Let R be a complete discrete valuation ring of mixed characteristic $(0, p)$. Finite, flat, commutative, cocommutative Hopf R-Hopf algebras of p-power rank are classified by Kisin modules. We will describe when a Kisin module corresponds to an R-Hopf algebra which is monogenic, i.e., generated as an algebra by a single element. (Received September 17, 2013)

1096-14-2109 **Sean T Paul*** (stpaul@math.wisc.edu), Department of Mathematics, University of Wisconsin, 480 Lincoln Drive, Madison, WI 53706. *Introduction to Canonical Kahler metrics and Semistable Pairs.*

One of the main problems in complex geometry is to detect the existence of "canonical" Kahler metrics in a given Kahler class on a compact complex polarized manifold. Work on this question eventually led to an interesting conjecture-the "Tian-Yau-Donaldson" conjecture which relates the existence of these special metrics (on an algebraic manifold) to the geometry of its "Kodaira images". Early work of Tian suggested that K-energy lower bounds (as well as the important coercive estimate) along Bergman potentials could be deduced from an appropriate notion of semistability. Recently, this has been worked out by the speaker (building upon work of Gang Tian and Gelfand-Kapranov-Zelevinsky and Weyman-Zelevinsky) and it is the aim of this talk to discuss the entire Theory in the context of complex algebraic groups and dominance of rational representations of such groups. (Received September 17, 2013)

1096-14-2167 **Lorenzo Fantini*** (`lorenzo.fantini@wis.kuleuven.be`). *Normalized Berkovich spaces and surface singularities.* Preliminary report.

In this talk I will discuss an application of Berkovich spaces to the study of surface singularities over an arbitrary field. Berkovich theory is a branch of non-archimedean geometry developed by Vladimir Berkovich in the late '80s; the points of Berkovich spaces can be interpreted as real semivaluations. I will give a new proof of the existence of resolutions of singularities of surfaces. To do so, I will introduce the normalized space of an algebraic variety, which is a generalization of Favre and Jonsson's Valuative Tree, and study its geometry and analytic structure. I will also deduce a characterization of the divisorial valuations whose center on every log resolution of a given normal surface is a divisor. (Received September 17, 2013)

1096-14-2182 **Amy Ksir** (`ksir@usna.edu`) and **Caroline Grant Melles*** (`cgg@usna.edu`). *Automorphisms of genus 2 Berkovich analytic curves and their skeletons.*

Let K be an algebraically closed non-Archimedean field which is complete with respect to a non-trivial Archimedean valuation. For each smooth projective algebraic curve X over K, there is a Berkovich analytification X^*. When X has genus at least 1, there is a unique minimal skeleton Σ in X^* with the structure of a finite metric graph. An automorphism of X induces an automorphism of X^* which restricts to a metric graph automorphism of Σ.

We study the homomorphism of automorphism groups $\mathrm{Aut}(X^*) \to \mathrm{Aut}(\Sigma)$ for some examples. We use examples in which X has genus 2 to show that this homomorphism is not necessarily injective or surjective. We investigate conditions that must hold for a metric graph automorphism of Σ to be the restriction of an automorphism of X^*. (Received September 17, 2013)

1096-14-2342 **James S. Wolper***, wolpjame@isu.edu. *Information Theory and Moduli of Riemann Surfaces.* Preliminary report.

One interpretation of Torelli's Theorem, which asserts that a compact Riemann Surface X of genus $g > 1$ is determined by the $g(g+1)/2$ entries of the period matrix, is that the period matrix is a message about X. Since this message depends on only $3g-3$ moduli, it is sparse, or at least approximately so, in the sense of information theory. Thus, methods from information theory may be useful in reconstructing the period matrix, and hence the Riemann surface, from a small subset of the periods. The results here show that, with high probability, any set of $3g-3$ periods form moduli for the surface. (Received September 17, 2013)

1096-14-2369 **Nikola Penev** and **Ravi Vakil*** (`vakil@math.stanford.edu`). *The Chow ring of the moduli space of genus 6 curves.*

We determine the Chow ring (with rational coefficients) of the moduli space of curves of genus 6 by showing that all Chow classes are tautological. In particular, all algebraic cohomology is tautological, and the natural map from Chow to cohomology is injective. We rely on results of many others, notably Faber, Vistoli, and Mukai. To show the efficacy of these methods, we give quick derivations of the Chow groups of moduli spaces of curves of lower genus as well. What makes genus 6 argument tractable (and even short) is the particularly beautiful Brill-Noether theory in this case. This is joint work with Nikola Penev. (Received September 17, 2013)

1096-14-2376 **Melanie Matchett Wood** and **Ravi Vakil*** (`vakil@math.stanford.edu`). *From combinatorics to motives: Cutting and pasting in algebraic geometry.*

Given some class of "geometric spaces", we can make a ring as follows.

(i) *(additive structure)* When U is an open subset of such a space X, $[X] = [U] + [(X \setminus U)]$;

(ii) (multiplicative structure) $[X \times Y] = [X][Y]$.

In the algebraic setting, this ring (the "Grothendieck ring of varieties") contains surprising structure, connecting geometry to arithmetic and topology. I will discuss some remarkable statements about this ring (both known and conjectural), and present new statements (again, both known and conjectural). A motivating example will be polynomials in one variable. The key to these results is understanding the combinatorial structure related to "symmetric powers".

This is joint work with Melanie Matchett Wood. (Received September 17, 2013)

1096-14-2397 **Dan Bates**, **Dan Brake** and **Matthew Niemerg*** (niemerg@math.colostate.edu), Matthew Niemerg, Colorado State University, Mathematics Department, Fort Collins, CO 80523-1874. *An Introduction to Parameter Homotopies and paramotopy.*

For many applications arising in science and engineering one wants to solve a polynomial system with the same monomial structure but with different coefficient values. This talk will provide an introduction to parameter homotopies. (Received September 17, 2013)

1096-14-2405 **Alexander Soibelman*** (asoibel@live.unc.edu), UNC Phillips Hall, Mathematics Dept #3250, Chapel Hill, NC 27599. *The moduli stack of parabolic bundles and the additive Deligne-Simpson problem.*

The "very good" property for smooth complex equidimensional algebraic stacks was introduced by Beilinson and Drinfeld in their paper "The Quantization of Hitchin's Integrable System and Hecke Eigensheaves". They proved that for a semisimple complex group G, the moduli stack of G-bundles over a smooth complex projective curve X is "very good" as long as X has genus g greater than 1. We will define the "very good" property for algebraic stacks and prove it for the moduli stack of parabolic bundles over $\mathbb{P}^1$. As a special case, we will consider the "very good" property for the quotient stack arising from the diagonal action of the group PGL(n) on a product of partial flag varieties and its relationship with the space of solutions to the additive Deligne-Simpson problem. (Received September 17, 2013)

1096-14-2409 **Merrick L Brown***, Dept of Math CB #3250, University of North Carolina, Chapel Hill, NC 27599. *A Study of the Saturated Tensor Cone for Symmetrizable Kac-Moody Algebras.*

Let $\mathfrak{g}$ be a symmetrizable Kac-Moody Lie Algebra and let $G^{\min}$ be the 'minimal' Kac-Moody group with Lie algebra $\mathfrak{g}$. We give a set of necessary inequalities satisfied by the saturated tensor semigroup indexed by products in $H^*(G^{\min}/B, \mathbb{Z})$ for B the standard Borel subgroup. The proof relies on the Kac-Moody analogue of the Borel-Weil theorem and Geometric Invariant Theory (specifically the Hilbert-Mumford index). In the case that $\mathfrak{g}$ is affine of rank 2, we show that these inequalities are necessary and sufficient. (Received September 17, 2013)

1096-14-2412 **Nathaniel F Bushek*** (bushek@unc.edu), 10 Mt Bolus Rd, Chapel Hill, NC 27514. *Hitchin's conjecture for simply-laced Lie algebras implies that for any simple Lie algebra.*

Let $\mathfrak{g}$ be any simple Lie algebra over $\mathbb{C}$. Recall there exists a princpal TDS embedding of $\mathfrak{sl}_2$ into $\mathfrak{g}$ passing through a principal nilpotent of $\mathfrak{g}$. $\wedge(\mathfrak{g}^*)^{\mathfrak{g}}$ is generated by primitive elements $\omega_1, \ldots, \omega_\ell$, where ℓ is the rank of $\mathfrak{g}$. N. Hitchin conjectured that for any primitive element $\omega \in \wedge^d(\mathfrak{g}^*)^{\mathfrak{g}}$, there exists an irreducible $\mathfrak{sl}_2$-submodule V_ω of dimension d such that ω is non-zero on $\wedge^d(V_\omega)$. The main motivation for Hitchin behind this conjecture lies in its connection with the study of polyvector fields on the moduli space $M_G(\Sigma)$ of semistable principal G-bundles on a smooth projective curve Σ of any genus $g > 2$. We prove that the validity of this conjecture for simple simply-laced Lie algebras implies its validity for any simple Lie algebra. Let G be a connected, simply-connected simple simply-laced algebraic group and K the fixed subgroup of a diagram automorphism of G. We show that the restriction map of representation rings, $R(G) \to R(K)$, is surjective. Our proof of the reduction of Hitchin's conjecture depends on this surjectivity. (Received September 18, 2013)

1096-14-2466 **Kevin Purbhoo*** (kpurbhoo@uwaterloo.ca), Combinatorics & Optimization Department, University of Waterloo, 200 University Ave. W., Waterlo, Ontario N2L 3G1, Canada. *Young tableaux and subvarieties of the Grassmannian.*

The Wronski map from a Grassmannian to projective space gives a way to label certain points on the Grassmannian by standard Young tableaux. One can use this correspondence to define subvarieties of the Grassmannian from a tableau or a class of tableaux. This perspective provides a direct link between geometric and combinatorial properties of these subva- rieties. We will discuss a few of interesting examples, including the orthogonal and Lagrangian Grassmannians. (Received September 17, 2013)

1096-14-2470 **Corey Harris*** (charris@math.fsu.edu). *Monomial Principalization in the Singular Setting.*

We generalize an algorithm by Goward for principalization of monomial ideals in nonsingular varieties to work on any scheme of finite type over a field. The normal crossings condition considered by Goward is weakened to the condition that components of the generating divisors meet as complete intersections. (Received September 17, 2013)

1096-14-2516 **Marton Hablicsek*** (hablics@math.wisc.edu), 922 B Eagle hts, Madison, WI 53705, and **Andrei Caldararu** and **Dima Arinkin**. *Derived intersections and the Hodge theorem.*

I will present a base change theorem for non-transversal intersections of smooth subvarieties in a smooth variety. As an application I will give a new, algebraic proof of the Hodge decomposition (along the lines of Deligne and Illusie). Similar techniques can also be used to prove a special case of a result of Barannikov-Kontsevich computing the cohomology of the twisted de Rham complexes. This work is joint with Dima Arinkin and Andrei Caldararu. (Received September 17, 2013)

1096-14-2737 **M Brandon Meredith*** (mbmeredith@ucsd.edu). *Mirror Symmetry on Toric Surfaces via Tropical Geometry.*

Mirror symmetry is a curious duality, first noticed by physicists and then excitedly embraced by mathematicians, between certain manifolds (the A-side) and their "mirror" spaces (the B-side). On the A-side, certain counts of objects on a manifold are carried out (the purview of enumerative geometry), while on the B-side, special functions are integrated. Interestingly, the same numbers come out on both sides.

This talk considers mirror symmetry on toric surfaces, which are varieties with certain convenient combinatorial properties and include many well-known surfaces such as the affine and projective planes and $\mathbb{P}^1 \times \mathbb{P}^1$. These surfaces are especially suited to being exploited by tropical geometry, which is a form of algebraic geometry over the "tropical semi-ring." Dramatically, key information about both sides of mirror symmetry on toric surfaces can be gleaned from the tropics.

The mirror symmetry of a certain subclass of toric varieties, those that are Fano, has seen much progress. This talk will discuss a generalization to non-Fano toric surfaces, where some curves are "hidden" from the viewpoint of tropical geometry. We will discuss how we verified these methods by carrying out explicit calculations on the second Hirzebruch surface. (Received September 18, 2013)

1096-14-2740 **Eric Larson** (elarson3@gmail.com). *Maximal Rank for Sections of Curves.*

Let C be a general curve of genus g embedded via a general linear series of degree d in P^r. The well-known Maximal Rank Conjecture asserts that the restriction maps $H^0(O_{P^r}(m)) \to H^0(O_C(m)$ are of maximal rank; if known, this conjecture would determine the Hilbert function of C.

In this talk, we will discuss the analogous problem involving the hyperplane sections of general curves, and explain its relevance to the maximal rank conjecture.
(Received September 18, 2013)

15 ► Linear and multilinear algebra; matrix theory

1096-15-129 **Alice Chan**, **Martin S. Copenhaver**, **Sivaram K. Narayan**, **Logan Stokols** and **Allison Theobold*** (atheobol@mavs.coloradomesa.edu). *Combinatorial Structure of Finite Frames.* Preliminary report.

A *frame* in an n-dimensional Hilbert space H_n is a possibly redundant collection of vectors $\{f_i\}_{i\in I}$ that span the space. A *tight* frame is a generalization of an orthonormal basis. A frame $\{f_i\}_{i\in I}$ is said to be *scalable* if there exist nonnegative scalars $\{c_i\}_{i\in I}$ such that $\{c_i f_i\}_{i\in I}$ is a tight frame. Here we study the combinatorial structure of frames and their decomposition into tight or scalable subsets. We prove conditions which these decompositions must satisfy and use these to fully determine when a frame in H_2 exists with a given tight subframe decomposition. We also study when a frame can be scaled to have a given tight subframe decomposition. This research was done as part of the Central Michigan University REU program. (Received August 02, 2013)

1096-15-232 **Arthur Lim** (arthurlim@nd.edu), 255 Hurley, South Bend, IN 46556, and **Jialing Dai*** (jdai@pacific.edu), 3601 Pacific Ave, Stockton, CA 95211. *On Product of Companion Matrices.*

This paper describes an explicit combinatorial formula for a product of companion matrices. The method relies on the connections between matrix algebra and associated combinatorial structures to enumerate the paths in an unweighted digraph. As an application, we obtain bases for the solution space of the linear difference equation with variable coefficients. (Received August 21, 2013)

1096-15-319 **Steven Osborne*** (sosborne@iastate.edu), 396 Carver Hall, Ames, IA 50011. *Almost all trees are normalized Laplacian cospectral.*

It is known that almost all trees have a cospectral mate for the adjacency, Laplacian and signless Laplacian matrices. We show that almost all trees have a cospectral mate for the normalized Laplacian matrix as well.
(Received August 28, 2013)

1096-15-815 **Crista Arangala** and **Nakhila Mistry*** (nmistry@elon.edu). *Music Genomics: Applying Seriation Algorithms to Billboard #1 Hits.*

Music plays a prominent role in society and companies have even started studying its aspects for commercial purposes. It is only natural to ask what are the characteristics that make certain songs appealing. While much research has been conducted on the mathematical principles of sound, there has been less focus on analyzing the structure of popular songs from a mathematical perspective. One mathematical tool that researchers have used to study this is seriation, ordering. Seriation algorithms are frequently used for companies with an online presence, including Google, Facebook, Amazon, and Pandora, to understand the traits of what users like in order to attract more consumers. We will use these types of seriation algorithms to conduct a mathematical analysis of the structural qualities of music. We will test whether the same structural traits appear in an artist's songs as the songs of the artists that they cite as musical influences. In order to musically link the chosen artists, we will use applied linear algebra methods. Results show that an artist's songs have a higher quantitatively measured connection with the artists they cite as influences rather than the artists who they never mention as musical influences. (Received September 10, 2013)

1096-15-915 **Viktoria Taroudaki*** (victtar@math.umd.edu) and **Dianne P. O'Leary**. *Image estimation using optimal filters.* Preliminary report.

The image restoration is a challenging inverse problem. Solutions involving filters have been proposed. In the past we have used statistical analysis and observed properties of the noise to estimate the optimal parameter for the truncated SVD filter. In this work, we extend this analysis to other known filters such as the TSCM, the Truncated Tikhonov, and to combinations of them. The resulting restorations compare favorably to those using parameters estimated through well studied methods and are not much different from restorations using the true (generally unknown) optimal parameter. (Received September 11, 2013)

1096-15-1190 **Adam Coffman***, 2101 E. Coliseum Blvd., Department of Mathematical Sciences, IPFW, Fort Wayne, IN 46805. *Real linear maps preserving some complex subspaces.*

We find configurations of subspaces of a complex vector space such that any real linear map with sufficiently high rank that maps the subspaces into complex subspaces of the same dimension must be complex linear or antilinear. (Received September 13, 2013)

1096-15-1325 **Graham Denham**, **Mehdi Garrousian*** (mgarrou@uwindsor.ca) and **Stefan Tohaneanu**. *Arrangements with quadratic complete intersection Orlik-Terao algebras.*

The Orlik-Terao algebra of an arrangement is the coordinate ring of the reciprocal compactification of the arrangement complement and provides a commutative analog of the Orlik-Solomon algebra. In the presence of a modular flat, we obtain a decomposition of the OT algebra into the OT algebras of the localization and the fiber arrangement. Consequently, when the arrangement is supersolvable, the OT algebra is Koszul and in fact G-quadratic. Furthermore, we refine this result by giving combinatorial characterizations of the quadratic complete intersection property. (Received September 14, 2013)

1096-15-1567 **Greg Knese*** (geknese@math.wustl.edu), Washington University in St. Louis, Department of Mathematics, One Brookings Drive, Campus Box 1146, St. Louis, MO 63105. *Determinantal representations of semi-hyperbolic polynomials.*

We prove a generalization of the Hermitian version of the Helton-Vinnikov determinantal representation of hyperbolic polynomials to the class of semi-hyperbolic polynomials, a strictly larger class, as shown by an example. We also prove that certain hyperbolic polynomials affine in two out of four variables divide a determinantal polynomial. The proofs are based on work related to polynomials with no zeros on the bidisk and tridisk. (Received September 16, 2013)

1096-15-1674 **Charles R Johnson** and **Sivaram K Narayan*** (sivaram.narayan@cmich.edu), Department of Mathematics, Central Michigan University, Mount Pleasant, MI 48859. *The Koteljanskii Inequalities for Mixed Matrices.*

Recently, a new class of matrices, called mixed matrices, that unifies the Z-matrices and symmetric matrices has been identified. They share the property that when the leading principal minors are positive, all principal minors are positive. It is natural to ask what other properties of M-matrices and positive definite matrices are enjoyed by mixed matrices as well. Here, 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. (Received September 16, 2013)

1096-15-2004 **Keivan Hassani Monfared*** (k1monfared@gmail.com), 1000 E. University Ave. Dept 3036, Laramie, WY 82071, and **Bryan L Shader** (bshader@uwyo.edu), 1000 E. Univerrsity Ave. Dept 3036, Laramie, WY 82071. *The Jacobian method and structured inverse eigenvalue problems.*

We have used the Jacobian method to find solutions to some structured inverse eigenvalue problems (SIEP). Some combinatorial methods are used by A.L. Duarte to find a solution to an SIEP where the structure comes from a tree. We have shown that the solution is generic, using some algebraic tools. Then by the means of the implicit function theorem the solution is extended to connected graphs. (Received September 17, 2013)

1096-15-2184 **Stephen Philip Cameron*** (spcameron@email.wm.edu) and **Christino Tamon** (ctamon@gmail.com). *Universal State Transfer.*

A Hermitian graph is a directed, complex weighted graph with a Hermitian adjacency matrix. Given a Hermitian graph G with adjacency matrix A, a continuous-time quantum walk on G is given by the unitary matrix $U(t) = exp(-itA)$. We say that G has "pretty good state transfer" (PGST) from vertex a to vertex b if $|U(t)_{b,a}|^2$ can be made arbitrarily close to unity, and "perfect state transfer" (PST) if equality is achieved. In this work, we examine graphs with "universal" state transfer, where pretty good/perfect state transfer occurs between all pairs of vertices. Recently, Godsil et al. (2012) proved that a certain family of paths has PGST between antipodal vertices. In a similar vein, we prove that there is a family of Hermitian cycles with universal PGST. Moreover, we give sufficient conditions for a permutation matrix to lie in the closure of $\{U(t) : t \in \mathbb{R}\}$, and use this to prove that the automorphism group of any universal PGST graph is abelian, with its order dividing the order of the graph. We then examine circulant graphs, and give necessary and sufficient conditions for universal PST to occur in terms of the spectrum of the graph. Finally, we give an example of a nontrivial, real weighted graph with universal PGST. (Received September 17, 2013)

1096-15-2245 **Jason J Molitierno*** (molitiernoj@sacredheart.edu), Department of Mathematics, Sacred Heart University, 5151 Park Avenue, Fairfield, CT 06825-1000. *Ordering maximal planar graphs by algebraic connectivity.*

Given an unweighted graph on n vertices with vertices labelled $1, \ldots, n$, the Laplacian matrix for the graph is the $n \times n$ matrix whose i^{th} diagonal entry is the degree of vertex i and the (i, j) entry is -1 if vertices i and j are adjacent and 0 if vertices i and j are not adjacent. The Laplacian matrix for a graph is positive semidefinite, hence its eigenvalues can be ordered $0 = \lambda_1 \leq \lambda_2 \ldots \leq \lambda_n$. The eigenvalue λ_2 is known as the algebraic connectivity of a graph as it gives a measure of how connected the graph is. We will first show that for all planar graphs $\mathcal{G}$ that $\lambda_2(\mathcal{G}) \leq 4$. We then find a smaller upper bound on planar graphs whose minimum degree is five and show which class of graphs achieves this upper bound. We then determine all maximal planar graphs with minimum degree three or four that have a larger algebraic connectivity than all maximal planar graphs with minimum degree five. (Received September 17, 2013)

1096-15-2428 **Justin Marks*** (jmarks@bowdoin.edu), **Matthew Fickus** and **Miriam J. Poteet**. *Constructing optimal finite frames with a given set of lengths.*

When constructing finite frames for a given application, the most important consideration is the spectrum of the frame operator. Indeed, the minimum and maximum eigenvalues of the frame operator are the optimal frame bounds, and the frame is tight precisely when this spectrum is constant. Often, the second-most important design consideration is the lengths of frame vectors. For instance, unit norm tight frame-based encoding is known to be optimally robust against additive noise and erasures. We consider the problem of constructing frames such that the corresponding frame operator has an optimal spectrum and whose vectors have prescribed lengths. For a given spectrum and set of lengths, the existence of such frames is characterized by the Schur-Horn Theorem—they exist if and only if the spectrum majorizes the squared lengths—the classical proof of which is nonconstructive. Certain construction methods are known in special cases. In this talk, we introduce an algorithm to construct the optimal frame in the general case, building from a given initial frame with known spectrum. We describe the proof of optimality of the constructed frame. (Received September 17, 2013)

16 ► *Associative rings and algebras*

1096-16-405 **Nicholas J Werner*** (nwerner@newark.osu.edu), 1179 University Drive, Newark, OH 43055. *Polynomials that kill each element of a finite ring.*

Given a finite (associative, unital) ring R, let $K(R)$ denote the set of polynomials in $R[x]$ that send each element of R to 0 under evaluation. We will discuss $K(R)$ and its elements. We conjecture that $K(R)$ is a two-sided ideal of $R[x]$ for any finite ring R, and will present several classes of finite rings (including commutative rings, semisimple rings, local rings, and all finite rings of odd order) for which the conjecture is true. We will also consider a connection to sets of integer-valued polynomials. (Received September 02, 2013)

1096-16-852 **Andrew Jaramillo*** (drewj@math.ucsb.edu), Santa Barbara, CA. *Quantum Subgroups of SL_n.* Preliminary report.

The subject of Quantum Groups originated in the mid 1980's in the Leningrad School when studying the quantum inverse scattering method. Since that time, there has been much progress on Quantum Groups; however, there is still no definition for them. One guiding principle for these objects is that they are noncommutative k-algebras with parameter q where as $q \to 1$ we recover a classical object.

Though we will not attempt give such a definition for "Quantum Groups" here, we will give a brief overview of some mathematical objects which are considered "Quantum" as well as some of the tools used in their study. This talk will delve into Hopf Algebras, Hopf Duality, as well as investigating the structure of the quantized coordinate rings for subgroups of SL_n . Finally, we will propose some examples of noncommutative algebras which may be considered quantized coordinate rings for standard parabolic subgroups and their unipotent radicals in SL_n. (Received September 10, 2013)

1096-16-1290 **Norihiro Nakashima*** (naka_n@math.sci.hokudai.ac.jp), Kita 10, Nishi 8, Kita-Ku, Sapporo, Hokkaido 060-0810, Japan. *A construction for canonical systems of basic invariants for reflection groups.* Preliminary report.

Let V be a real Euclidean space, and $W \subseteq O(V)$ a finite reflection group. We denote by S the set of polynomial functions on V. Then W naturally acts on S. It is well known that the subalgebra of S consisting of invariant polynomials is generated by n algebraically independent homogeneous polynomials. A system of such generators is called a system of basic invariants.

A canonical system of basic invariant was introduced by Flatto and Wiener for solving a mean value problem related with the W-orbit of a point in V. It is known that there exists a canonical system for all finite real reflection groups. Iwasaki determined the structure of the vector space consisting of real valued continuous functions satisfying the mean value property on a regular convex polytope. Explicit formulas of canonical systems play an important part in the proof by Iwasaki. Explicit formulas of canonical systems of types A, B, D, F, H and I are already given. That problem of type E is still opened.

In this talk, we will give a construction for the explicit formulas of canonical systems. The construction does not depend on the classification of finite irreducible reflection groups. This is based on a joint work with S. Tsujie. (Received September 14, 2013)

1096-16-1320 **Adam S. Sikora*** (asikora@buffalo.edu), 244 Math Bldg, University at Buffalo, SUNY, Buffalo, NY 14260. *Unification of associative, self-distributive, and Lie algebras.* Preliminary report.

We define a new class of rings which unifies associative rings, self-distributive rings, and Lie algebras. We will discuss their fundamental properties and their cohomology theory unifying cohomology theories of these different types of algebras. (Received September 14, 2013)

1096-16-1638 **Gaohong Wang*** (gwang72@uwo.ca), Department of Mathematics, University of Western Ontario, London, Ontario N6A 5B7, Canada. *The Ghost Number for a Finite Group.*

The generating hypothesis can be asked in general on a triangulated category. Previous work has shown that it fails on a stable module category of a group algebra for most finite groups, and it will be interesting to know the degree to which the generating hypothesis fails. We study the ghost number of the group algebra which measures this. We apply the idea of a projective class in the study, and show some relationships between the ghost number and other invariants. (Received September 16, 2013)

1096-16-1730 **Andrew Conner*** (connerab@wfu.edu), **Thomas Cassidy**, **Ellen Kirkman** and **W. Frank Moore**. *Periodic free resolutions from twisted matrix factorizations.*

The notion of a matrix factorization was introduced by Eisenbud in the commutative case in his study of bounded (periodic) free resolutions over complete intersections. Since then, matrix factorizations have appeared in a number of applications. In this talk, we extend the notion of (homogeneous) matrix factorization to normal, regular elements in noncommutative graded algebras and use these factorizations to construct periodic free resolutions. (Received September 16, 2013)

1096-16-1766 **G. Griffith Elder*** (elder@unomaha.edu), Department of Mathematics, University of Nebraska at Omaha, Omaha, NE 68182-0243. *Hopf orders in group rings over local fields.* Preliminary report.

Let K be a complete local field with perfect residue field of characteristic p, and let G be a p-group. In 1970, Tate and Oort classified Hopf algebras over the valuation ring O_K (i.e. Hopf orders) in $K[G]$ where G has order p. When G has order p^2, the Hopf orders in $K[G]$ were classified separately by Greither (1992) and Byott (1993). Since then, there have been a number of papers by Underwood and Childs (including others) describing families of Hopf orders in $K[G]$ for K of characteristic 0 and G either elementary abelian or cyclic with $|G| = p^n$ and $n \geq 3$. These descriptions require that the pth roots of unity lie in K and thus are intrinsically characteristic 0. Notably, the classifications for $n = 3$ remain incomplete. I will describe a characteristic independent approach to the description of Hopf orders. Letting G be elementary abelian of degree $\geq p^3$ (for the purposes of illustration), Hopf orders are first determined in characteristic p, then lower bounds on the absolute ramification $v_K(p)$ are determined so that the result continues to hold in characteristic 0. The resulting Hopf orders can then be compared with those of Greither-Childs (1998) and Childs-Smith III (2005). (Received September 16, 2013)

1096-16-1800 **Alex Hoffnung*** (hoffnung@temple.edu), **Jose Malagon-Lopez**, **Alistair Savage** and **Kirill Zainoulline**. *Formal Hecke algebras and algebraic oriented cohomology theories.*

We define two families of algebras depending on a formal group law associated to an algebraic oriented cohomology theory. These recover the nil Hecke ring of Kostant and Kumar and important Hecke algebras in certain cases and yield apparently new algebras in other cases, which do not satisfy the usual braid relation, but rather a new relation which we call the "oriented braid relation". (Received September 16, 2013)

1096-16-1836 **Tyler Kloefkorn*** (tkloefko@uoregon.edu). *Splitting Algebras: Koszul and Cohen-Macaulay.*

Within a well-known class of algebras, we study a connection between noncommutative homological algebra and combinatorial topology. To a finite ranked poset Γ we associate a finite-dimensional quadratic graded algebra R_Γ. Assuming Γ satisfies a combinatorial condition known as uniform, R_Γ is the quadratic dual of the associated graded splitting algebra A'_Γ. Gelfand, Retakh, Serconek and Wilson first introduced splitting algebras and a subset of these authors showed that a splitting algebra A_Γ is quadratic if Γ is uniform. Given a uniform Γ, we then ask a standard question in noncommutative homological algebra: Does A_Γ satisfy the Koszul property? Applying standard techniques and assuming the uniform hypothesis, it is known that if R_Γ is Koszul, then so is A_Γ. We therefore study Koszulity of R_Γ in search of necessary and sufficient conditions on Γ. We have found that the Koszulity of R_Γ is related to a combinatorial topology property of Γ known as Cohen-Macaulay. This property is ubiquitous and it often connects the fields of algebra and topology. We prove: Γ is Cohen-Macaulay if and only if Γ is uniform and R_Γ is Koszul. (Received September 16, 2013)

17 ► Nonassociative rings and algebras

1096-17-299 **Victoria Lebed*** (lebed.victoria@gmail.com). *Self-, multi- and G-distributivity with a braided flavor.*

The growing interest in self-distributive structures and especially in their homology theory is largely due to their remarkable applications to knot theory. In this talk we will recall the more general theory of multi-distributive structures (in the sense of Przytycki and Sikora), and then introduce an even more general notion of multi-braided structures and develop their homology theory. In order to illustrate the richness of the latter notion, we recover Poisson algebras as a particular case of multi-braided structures. Colored braids and links will appear as topological counterparts of our constructions. Endowing the set of colors with additional structure leads, among others, to the notion of G-families of quandles introduced by Ishii, Iwakiri, Jang and Oshiro in their work on handlebody-knot invariants. (Received August 27, 2013)

1096-17-363 **Irfan Bagci***, Department of Mathematics, University of North Georgia, 3820 Mundy Mill Rd, Oakwood, GA , and **Samuel Chamberlin**, Computer Science and Math Dept, Parkville, MO 64152. *Integral forms and integral bases for universal enveloping algebras of map superalgebras.*

Let $\mathfrak{g}$ be a finite dimensional complex simple Lie superalgebra and A be a commutative, associative algebra with unity over $\mathbb{C}$. In this talk we will 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 August 30, 2013)

1096-17-580 **Houssein El Turkey*** (houssein@ou.edu), University of Oklahoma, Mathematics Department, 460 Elm Ave., 73069 Norman, OK. *Complexity of modules over Lie superalgebras.*

The complexity of a module is the rate of growth of a minimal projective resolution of the module. In this talk the complexity is computed for the Kac and the simple modules over the Lie superalgebra of type C. Then, a geometric interpretation is given via the theory of support varieties. We also compute the complexity of the simple modules over the exceptional Lie superalgebras $D(2,1;\alpha)$ and $G(3)$. (Received September 06, 2013)

1096-17-1201 **Charles H Conley** (conley@unt.edu), Department of Mathematics, University of North Texas, Denton, TX 76203, and **Rabin Dahal*** (rabin.dahal@unt.edu), Department of Mathematics, University of North Texas, Denton, TX 76203. *Centers of invariant differential operator algebras for Jacobi groups of higher rank.*

Let G be a Lie group acting on a homogeneous space G/K. The center of the universal enveloping algebra of the Lie algebra of G maps homomorphically into the center of the algebra of differential operators on G/K invariant under the action of G. In the case that G is a Jacobi Lie group, we prove that this homomorphism is surjective and hence that the center of the invariant differential operator algebra is the image of the center of the universal enveloping algebra. This is an extension of work of the first author with Bringmann and Richter in the rank 1 case. (Received September 13, 2013)

1096-17-1598 **Allison McAlister Hedges*** (armcalis@ncsu.edu), Department of Mathematics, Box 8205, North Carolina State University, Raleigh, NC 27695. *Cyclic Leibniz Algebras.*

Leibniz algebras are a generalization of Lie algebras. A common goal in the study of these algebras is to determine which Lie algebra results can successfully be generalized to the Leibniz case. A simple example of a Leibniz algebra that is not Lie is a cyclic algebra generated by one element, a, where $a^2 \neq 0$. We use this algebra to produce illustrative examples of results that do generalize and some that do not. (Received September 16, 2013)

1096-17-2373 **Lindsey Bosko-Dunbar**, **Jonathan D Dunbar**, **J.T. Hird** and **Kristen Stagg*** (kstagg@uttyler.edu). *Solvable Leibniz Algebras with Heisenberg Nilradical.* Preliminary report.

All solvable Lie algebras with Heisenberg nilradical have been classified. This talk will extend the result to a classification of solvable Leibniz algebras with Heisenberg nilradical. (Received September 17, 2013)

1096-17-2649 **Krzysztof Karol Putyra*** (putyra@math.columbia.edu). *The many versions of odd Khovanov homology.* Preliminary report.

Khovanov homology is a link invariant that categorifies Jones polynomial. After it was defined by Khovanov in 1999, many other versions appeared: an embedded homology (Caprau-Stroppel), extensions for virtual links (Manturov) and tangles (Khovanov, Bar-Natan), a deformation by Lee and a theory based on dotted cobordisms (Bar-Natan) that was proven to be the universal one (Khovanov). The last one is also defined for knots in surfaces. Another extension to knots in surfaces was explored by Asada-Sikora-Przytycki. On the other hand, the odd Khovanov homology, defined by Ozsvath-Rasmussen-Szabo in 2007 has a different flavor and does not fit into any of the frameworks above.

In my talk I will show how to construct a theory covering both odd and ordinary homology and how to extend it for tangles. The key point is to use 2-categorical structure of cobordisms, pseudo-functorial tensor products and quasi-rings, i.e. rings that are associative only up to a sign. If time permits, I will also demonstrate how to obtain odd versions of embedded homology. The case of virtual links is still open. (Received September 17, 2013)

18 ► Category theory; homological algebra

1096-18-162 **Van C. Nguyen*** (vcnguyen@math.tamu.edu), Department of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77843-3368. *Finite generation behaves differently in negative cohomology.*

While the usual cohomology rings of some finite dimensional Hopf algebras are known to be finitely generated, the same may not be true when we extend them to negative cohomology. In particular, we investigate this property for a finite dimensional symmetric Hopf algebra A over a field k. It turns out that if a module in a connected component of the stable Auslander-Reiten quiver associated to A has finitely generated Tate cohomology, then so does every module in that component. We apply some of these finite generation results on Tate cohomology to a non-trivial example. (Received August 12, 2013)

1096-18-307 **Furuzan Ozbek*** (furuzanozbek@uky.edu), **Pedro Guil Asensio** (paguil@um.es) and **Sergio Estrada** (sestrada@um.es). *A Sufficient Condition for Covering Ideals.* Preliminary report.

Ideal approximation theory has been recently introduced by Herzog, Fu, Guil Asensio and Torrecillas. This theory establishes an extension to ideals of morphisms in exact categories of the usual theory of covers and envelopes by modules. In this talk we will give sufficient conditions for an ideal of morphisms to be covering and show how our result can be used to obtain an alternate proof for the existence of phantom covers. (Received August 27, 2013)

1096-18-1005 **Daniel Bravo**, **James Gillespie** and **Mark Hovey*** (mhovey@wesleyan.edu). *Gorenstein homological algebra.*

Gorenstein homological algebra is essentially the study of modules after sending certain modules to zero. In the simplest case of modular representation theory, projective and injective modules coincide and sending them to zero gives a triangulated category called the stable module category. Such a simple plan will not work for a general ring. We show, however, that by changing one's notion of a "finite" module from finitely generated or presented to modules of type FP_∞, we get good analogues of flat and injective modules that are well-behaved for any ring. This enables us to develop Gorenstein homological algebra and an associated triangulated stable module category in full generality. (Received September 12, 2013)

1096-18-1118 **Jean Goubault-Larrecq*** (goubault@lsv.ens-cachan.fr), LSV, ENS Cachan, 61, avenue du président Wilson, 94230 CACHAN, France. *The Escardó-Lawson-Simpson Construction.*

In 2004 (Topol. and its Applications 143), Escardó, Lawson, and Simpson proposed an elegant construction of Cartesian-closed full subcategories of $\mathbf{T}op$. The well-known subcategory of compactly-generated spaces is one example, and there are many others.

We shall show that their construction applies not only to $\mathbf{T}op$, but to any well-fibered topological construct $(\mathbf{C}, |\_|)$. The construction is parameterized by a class $\mathcal{C}$ of exponentiable objects that is closed under finite products, and proceeds in two steps. First, we build a category $\mathbf{M}ap$ whose objects are the same as in $\mathbf{C}$, but whose morphisms are, to say it roughly, set functions that are indistinguishable from morphisms in $\mathbf{C}$ from the point of view of $\mathcal{C}$. One easily shows that $\mathbf{M}ap$ is Cartesian-closed. In a second step, we show that $\mathbf{M}ap$ is equivalent to a coreflective subcategory $\mathbf{C}_\mathcal{C}$ of so-called $\mathcal{C}$-generated objects of $\mathbf{C}$.

This allows us to generalize a result of Krishnan (Appl. Cat. Structures 17, 2009) and provide many Cartesian closed categories of streams and prestreams. We also characterize the largest such (Exponentiable Streams and Prestreams, Appl. Cat. Structures, 2013). (Received September 13, 2013)

1096-18-1432 **Emily Riehl*** (eriehl@math.harvard.edu), Department of Mathematics, 1 Oxford Street, Cambridge, MA 02138. *Homotopy coherent adjunctions.*

We show that an adjoint functor between quasi-categories may be extended to a simplicially enriched functor whose domain is an explicitly presented "homotopy coherent adjunction". This adjunction data encapsulates both the homotopy coherent monad and comonad defined by the adjunction. Using this result, we construct the quasi-category of algebras associated to a homotopy coherent monad and give a formal re-proof of the classical monadicity theorem. This is joint work with Dominic Verity. (Received September 15, 2013)

1096-18-1513 **Anna Beliakova*** (anna@math.uzh.ch), University of Zurich, Institute of Mathematics, Winterthurerstr. 190, 8057 Zurich, Switzerland, and **Kazuo Habiro**. *Categorification of the ribbon element in quantum sl(2).*

Witten-Reshetikhin-Turaev invariants of any homology 3-sphere at all roots of unity are dominated by a certain generating function - called a unified invariant, which takes its values in the Habiro ring. This ring is a cyclotomic completion of the polynomial ring in one variable with integral coefficients.

In the talk we provide evidence to the fact that the unified invariants are more natural objects for categorification than the original invariants. A categorification program for unified invariants is based on a categorification of the universal sl(2) link invariant. For a knot this invariant belongs to the center of quantum sl(2).

Together with K. Habiro we recently made a crucial step towards a categorification of the universal R-matrix. We constructed an unbounded bicomplex which belongs to the Drinfeld center of the Khovanov-Lauda 2-category, whose Euler characteristic is the ribbon element of quantum sl(2). (Received September 16, 2013)

1096-18-1963 **Gábor Lukács*** (lukacs@topgroups.ca), Halifax, NS , Canada. *Duality of topological algebras and bornologies.*

This talk concerns extensions of well-known dualities of topological algebras: the Gelfand duality of commutative C^*-algebras, and the Pontryagin duality of locally compact abelian groups. A common feature of these extensions of classic dualities is that they use topological spaces equipped with a *bornology*, a notion modelled on bounded sets in metric spaces and relatively compact sets in a topological space.

It turns out that Gelfand duality extends to a duality between commutative pro-C^*-algebras and k_R-spaces whose topology is determined by a bornology of (some, but not necessarily all) relatively compact sets, while Pontryagin duality extends to the category of topobornological abelian groups, which has nice categorical properties. (Received September 16, 2013)

1096-18-2114 **Walter Tholen*** (tholen@mathstat.yorku.ca), Dept. of Mathematics and Statistics, York University, 4700 Keele Street, Toronto, Ontario M3J 1P3, Canada. *Dualizing closure operators.* Preliminary report.

Categorical closure operators have been studied for almost three decades now (see in particular the Dikranjan-Tholen and Castellini monographs) and may be regarded as an essential tool not only in categorical topology, but also in algebra, order and domain theory. What is the dual notion of closure operator? When dualized from a merely order-theoretic perspective, one arrives at Vorster's notion of interior operator (S. J. R. Vorster, Quaestiones Mathematicae 23 (2000) 405-416) that has found renewed interest in recent papers by Castellini, Holgate and Slapal. However, when the relevant subobject lattices are complemented, all interior operators are induced by closure operators. In this talk we investigate the categorically dualized notion, develop the theory and give a variety of examples from algebra and topology. This is joint work with Dikran Dikranjan. (Received September 17, 2013)

1096-18-2123 **Gavin J. Seal*** (gavin.seal@epfl.ch), Section of Mathematics, Station 8, EPFL, 1145 Lausanne, VD, Switzerland. *Multiordered sets as topological spaces.*

In this talk, we will give a brief overview of the theory of lax algebras by illustrating how multiordered sets can be studied from the viewpoint of topological spaces. In particular, we will demonstrate how concepts and results pertaining to concepts such as convergence, neighborhood systems, injective objects, or separation, can be formally transferred from the topological to the multiordered setting. (Received September 17, 2013)

1096-18-2430 **Denise Amanda Rangel*** (denise.rangel@mavs.uta.edu). *Totally Reflexive Modules and the AR-translate.* Preliminary report.

For $(R, \mathtt{m})$ a communicative local ring, we consider totally reflexive modules T over R and τ the Auslander-Reiten (AR) translate. We show that if $\tau(T)$ is a totally reflexive module, then R is Gorenstein provided $\mathtt{m}^3 = 0$. We will also investigate other means of potentially constructing AR-sequences, as well as other aspects of the AR-translate. (Received September 17, 2013)

19 ► K-theory

1096-19-201 **Michael Hartglass*** (hartglass.mike@gmail.com). *Guionnet, Jones, and Shlyakhtenko C^* algebras.*

Given a planar algebra, $\mathcal{P}$, Guionnet, Jones, and Shlyakhtenko constructed a family of graded algebras $Gr_k(\mathcal{P})$ associated to $\mathcal{P}$. They proved that their associated von Neumann algebras, M_k form a tower of interpolated free group factors whose standard invariant is $\mathcal{P}$. In this talk, we will examine the C^* algebras $\mathcal{A}_k$ associated to the family $Gr_k(\mathcal{P})$ and show that they have many interesting properties. In particular we will show that in many cases, the K-theory of these algebras has an aesthetically pleasing description. This is joint work with David Penneys. (Received August 16, 2013)

1096-19-384 **Rufus Willett*** (rufus@math.hawaii.edu), University of Hawaii Mathematics Department, 2565 McCarthy Mall, Keller 401A, Honolulu, HI 96822. *Expanders and K-theory.*

I'll survey problems caused by expanders for Baum-Connes type conjectures in K-theory. Although all expanders have some pathological properties with respect to these conjectures, some expanders are much worse than others. I'll discuss what's known about the metric properties that give rise to this, and how it relates to the Gromov monster groups that contain expanders in their Cayley graphs.

Some of this is from joint work with Guoliang Yu, and some from joint work with Paul Baum and Erik Guentner. (Received August 31, 2013)

1096-19-645 **Mona Mocanasu*** (mmocanas@msudenver.edu), MSU Denver, Mathematical And Computer Sciences Dep., P.O. Box 173362, Campus Box 38, Denver, CO 80217. *A Bivariant Theory for Quasi-Projective Schemes.*

In the *"Categorical Framework for the Study of Singular Spaces"* W. Fulton and R. MacPherson describe how bivariant theories can be used to study singular topological spaces. We modify and extend their approach to construct a bivariant theory that connects singular homology of quasi-projective schemes to cohomology with support for smooth pairs of schemes. This general construction is consistent with the known cases; for example, it connects singular Chow groups $CH^*(X)$ with the Operational Chow Groups for closed embeddings, $A^*(X \hookrightarrow Y)$.

We describe the most general type of 'pull-back' and 'push-forward' maps and list the conditions required for the existence of both these structures on a given theory. Moreover, our construction gives a compatible structure of higher Chern classes, fact that allows us to study the problem of a general Riemann-Roch theorem for singular homologies. (Received September 08, 2013)

1096-19-702 **Chi-Kwong Fok***, Department of Mathematics, Malott Hall, Cornell University, Ithaca, NY 14853. *The Real K-theory of compact Lie groups.*

In this talk I will first briefly review the previous work on the complex K-theory and Atiyah's KR-theory of compact Lie groups. Then I will present a complete description of the ring structure of the equivariant KR-theory of any compact, connected and simply-connected Lie group equipped with a Lie group involution. Time permitting, some applications and examples will also be discussed. (Received September 09, 2013)

1096-19-1825 **Elizabeth A. Gillaspy*** (elizabeth.a.gillaspy@dartmouth.edu), Dartmouth College, Department of Mathematics, 27 N. Main St., Hanover, NH 03755. *The effect of homotopies of groupoid 2-cocycles on C^*-algebraic K-theory.*

Groupoids at once generalize groups, group actions, equivalence relations, and group bundles. In his 1980 thesis, Renault explained how to construct a C^*-algebra $C^*(G, \omega)$ out of a groupoid G and a 2-cocycle $\omega \in Z^2(G, \mathbb{T})$. These twisted groupoid C^*-algebras answer many questions about the structure of other C^*-algebras, and their K-theory gives us information about D-branes in string theory.

When G is a group, Echterhoff et al. proved in 2010 that in many cases, a homotopy $\{\omega_t\}_{t\in[0,1]}$ of 2-cocycles on G leaves the K-theory groups of the twisted group C^*-algebras invariant:

$$K_*(C^*(G, \omega_0)) \cong K_*(C^*(G, \omega_1)).$$

We investigate the extent to which this K-theoretic invariance extends to the world of groupoids.

We have expanded Echterhoff et al.'s result to the case of transformation groups $G \ltimes X$; using different techniques, inspired by a 2012 result of Kumjian et al., we also show that a homotopy of 2-cocycles on the groupoid $\mathcal{G}_\Lambda$ associated to a k-graph Λ induces an isomorphism

$$K_*(C^*(\mathcal{G}_\Lambda, \omega_0)) \cong K_*(C^*(\mathcal{G}_\Lambda, \omega_1)).$$

This result suggests applications to the classification of k-graph C^*-algebras. (Received September 16, 2013)

20 ► Group theory and generalizations

1096-20-341 **Thomas Q. Sibley*** (tsibley@csbsju.edu). *Permutation Playthings and Transformation Toys.*

Puzzles and bells, mirrors and more can deepen student understanding of permutations and transformations, leading to concepts in group theory. Too often high school mathematics presents rotations, mirror reflections and other transformations as isolated items, rather than dynamic interactions. A variety of playthings can make compositions, subgroups and cosets natural concepts for students at all levels. These toys convey the power of group theory without requiring formal language and proofs, although they fit perfectly with them. (Received August 29, 2013)

1096-20-383 **Mark Sapir*** (m.sapir@vanderbilt.edu), 8025 Claytie Cir, Nashville, TN 37221-4629. *Uniform embedding of groups into Banach spaces.*

I will talk about results concerning embeddings of groups, especially finitely presented groups, in Hilbert and more general Banach spaces. (Received August 31, 2013)

1096-20-472 **Konstantin Medynets*** (medynets@usna.edu), Annapolis, MD 21401, and **Artem Dudko** (artem.dudko@stonybrook.edu). *Finite Factor Representations of Higman-Thompson Groups.*

We prove that the only finite factor-representations of the Higman-Thompson groups $\{F_{n,r}\}$, $\{G_{n,r}\}$ are the regular representations and scalar representations arising from group abelianizations. As corollaries, we obtain that any measure-preserving ergodic action of a the commutator subgroup of Higman-Thompson group must be essentially free and that these groups have no non-trivial invariant random subgroups. (Received September 04, 2013)

1096-20-608 **Matt Clay**, **Max Forester** and **Joel Louwsma*** (jlouwsma@ou.edu), Department of Mathematics, The University of Oklahoma, Norman, OK 73019. *Stable commutator length in Baumslag–Solitar groups.*

We obtain results both about computing stable commutator length in Baumslag–Solitar groups and about the spectrum of values it takes. In the first direction, we show that, for a certain class of elements, stable commutator length is computable and takes only rational values. We also determine exactly which elements of this class admit extremal surfaces. Our techniques additionally give lower bounds on the stable commutator length of all elements. In the second direction, we show that there is a uniform gap in the stable commutator length spectrum: no element of a Baumslag–Solitar group has stable commutator length between 0 and 1/12. Some of the techniques we use to show this apply more generally to other groups acting on trees. (Received September 07, 2013)

1096-20-646 **James Belk** and **Bradley Forrest*** (bradley.forrest@stockton.edu), 101 Vera King Farris Drive, Galloway, NJ 08205. *Thompson-like groups acting on Julia sets.*

We describe a family of groups acting on self-similar spaces, most notably Julia sets for certain quadratic polynomials. We discuss the relationships between these groups and the Thompson groups F, T, and V and Guba and Sapir's diagram groups. Our groups act on certain cubical complexes, and have finiteness properties corresponding to that action, and can be expressed through graph rewriting systems. (Received September 08, 2013)

1096-20-713 **Sang-hyun Kim** and **Thomas Koberda*** (thomas.koberda@gmail.com), PO Box 208283, New Haven, CT 06520-8283. *Right-angled Artin groups and finite subgraphs of curve graphs.* Preliminary report.

It is a result of the second author that if Γ is a finite subgraph of the curve graph of a surface S, then the right-angled Artin group $A(\Gamma)$ embeds in the mapping class group of S. We determine the surfaces for which the converse to this theorem holds. (Received September 09, 2013)

1096-20-737 **Arturo Magidin*** (magidin@member.ams.org), Mathematics Department, 217 Maxim Doucet Hall, P.O. Box 41010, Lafayette, LA 70504-1010. *A proof that a 4-generated group of class 2 and prime exponent is either cyclic, extra-special, or capable, using algebraic geometry.*

A group G is capable if $G \cong K/Z(K)$ for some K. It has long been known that nontrivial cyclic groups and extra-special p-groups of order greater than p^3 cannot be capable. The capability of groups of class 2 and prime exponent can be characterized in terms of certain subspaces and linear transformations between vector spaces over $\mathbb{F}_p$, and this set-up opens the door to other tools, in particular geometric tools, to enter the picture. In particular, we will show an argument using algebraic geometry to show that if G is of class two and prime exponent, and $|G^{\mathrm{ab}}| \leq p^4$, then the nontrivial cyclic group and the extra-special group of order p^5 and exponent p are in fact the only exceptions to capability. That is, such a group G is either non-trivial cyclic, extra-special of order p^5, or capable. The proof includes joint work with David McKinnon (University of Waterloo). (Received September 09, 2013)

1096-20-811 **Nic Koban*** (nicholas.koban@maine.edu). *The Bieri-Neumann-Strebel Invariant of the Pure Symmetric Automorphisms of a Right-angled Artin Group.*

In 1987, Bieri, Neumann, and Strebel introduced the geometric invariant $\Sigma^1(G)$ for a discrete group G. It is an open subset of a sphere associated to G known as the character sphere $S(G)$. Although $\Sigma^1(G)$ has proven quite difficult to compute in general, it has been computed in the case that G is the pure symmetric automorphism group of a free group. This is the group of basis conjugating automorphisms of a free group. In this talk, we generalize this result by computing $\Sigma^1(G)$ when G is the pure symmetric automorphism group of a right-angled Artin group. We also provide an application of this computation. It was shown that if A is the right-angled Artin group determined by a graph that has no separating intersection of links (no SILs), then the corresponding group of pure symmetric automorphisms is itself a right-angled Artin group. We use our calculation of Σ^1 of the pure symmetric automorphism group to prove the converse of this statement. (Received September 10, 2013)

1096-20-837 **Nathan E Bloomfield*** (nathan.e.bloomfield@gmail.com). *On partial algebras of full difunctional relations and dual symmetry.*

The set $\mathsf{Dif}(X)$ of all full and difunctional relations on a set X essentially consists of the bijections among the quotients of X, and so generalizes the symmetric group on X and dualizes the symmetric inverse semigroup on X. However, $\mathsf{Dif}(X)$ is only a partial algebra under relation composition. We exhibit an axiomatic class of partial algebras to which $\mathsf{Dif}(X)$ belongs and having the Cayley-like property that every instance M of this class embeds weakly in some $\mathsf{Dif}(X_M)$. This class of algebras simultaneously generalizes the classes of inverse semigroups, groupoids, and partially ordered sets under meet. (Received September 10, 2013)

1096-20-932 **Hyungryul Baik*** (hb278@cornell.edu), 111 Malott Hall, Department of Mathematics, Cornell University, Ithaca, NY 14850. *Fuchsian Groups, Circularly Ordered Groups, and Dense Invariant Laminations on the Circle.*

We propose a program to study groups acting faithfully on S^1 in terms of number of pairwise transverse dense invariant laminations. We give some examples of groups which admit a small number of invariant laminations as an introduction to such groups. Main focus of the present paper is to characterize Fuchsian groups in this scheme. We prove a group acting on S^1 is conjugate to a Fuchsian group if and only if it admits three very-full laminations with a variation of the transversality condition. (Received September 11, 2013)

1096-20-987 **Yan-Quan Feng*** (yqfeng@bjtu.edu.cn), Department of Mathematics, Beijing Jiaotong University, Beijing, 100044, Peoples Rep of China. *Graph symmetry and regular covering.*

Symmetries of a graph are measured by automorphisms of the graph, and regular covering of a graph was systematically investigated by Gross and Tucker in [Topological Graph Theory, John wiley and sons, 1987]. In this report, we talk about automorphisms of regular covers of a graph and their application to classification of arc-transitive graphs. (Received September 12, 2013)

1096-20-1151 **Samuel J Taylor*** (staylor@math.utexas.edu). *Subfactor projections for Out(F_n).*

This talk will introduce subfactor projections. These are the Out(F_n) version of subsurface projections, which have been used extensively to study mapping class groups. We will focus on this analogy and discuss a few application. (Received September 13, 2013)

1096-20-1347 **Johanna Mangahas*** (mangahas@math.brown.edu) and **Samuel J Taylor**. *Convex cocompactness in mapping class groups via quasiconvexity in right-angled Artin groups.*

We characterize convex cocompact subgroups of mapping class groups that arise as subgroups of specially embedded right-angled Artin groups. That is, if the right-angled Artin group G in Mod(S) satisfies certain conditions that imply G is quasi-isometrically embedded in Mod(S), then a purely pseudo-Anosov subgroup H of G is convex cocompact in Mod(S) if and only if it is combinatorially quasiconvex in G. We use this criterion to construct convex cocompact subgroups of Mod(S) whose orbit maps into the curve complex have small Lipschitz constants. (Received September 15, 2013)

1096-20-1437 **Elizabeth Wilcox*** (elizabeth.wilcox@oswego.edu), **Ben Brewster** and **Peter Hauck**. *Chermak-Delgado Chains in p-Groups of Small Order.*

The Chermak-Delgado lattice of a finite group G is the set of all subgroups $H \leq G$ such that $|H||C_G(H)|$ is maximal. This set is a modular self-dual sublattice of the subgroup lattice of G. In this talk the speaker will provide an explicit classification of p-groups P with $|P| \leq p^5$ and such that the Chermak-Delgado lattice of P is a chain of length 1. Additionally, a classification will be shared for p-groups P with order less than or equal to p^6 and a Chermak-Delgado lattice that is a chain of length 2. (Received September 15, 2013)

1096-20-1470 **Michael A. Jackson*** (majackson@gcc.edu). *The strong symmetric genus of some D-type 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 D-type generalized symmetric groups are the index m subgroups $D(n,m) = (C_m)^{n-1} \rtimes S_n$. The strong symmetric genus for the alternating and symmetric groups was found by Marston Conder. The author has also found the strong symmetric genus of the generalized symmetric groups of type $G(n,2)$, also known as the hyperoctahedral groups, $G(n,3)$ and the D-type generalized symmetric groups $D(n,2)$, which are the D_n

finite Coxeter groups. In this talk, we will look at the strong symmetric genus of additional D-type generalized symmetric groups. Using Marston Conder's coset diagrams for generators of the symmetric groups and some results about generating the D-type generalized symmetric groups, we can find the strong symmetric genus of many of these groups. (Received September 15, 2013)

1096-20-1477 **Pallavi Dani***, Department of Mathematics, 303 Lockett Hall, Louisiana State University, Baton Rouge, LA 70803, and **Anne Thomas**. *Large-scale geometry of certain right-angled Coxeter groups.*

I will discuss the quasi-isometry classification of 2-dimensional hyperbolic right-angled Coxeter groups and obtain a complete classification for the family defined by "generalized theta graphs". Time-permitting, I will discuss commensurability within this class, generalizing a result of Crisp and Paoluzzi. This is joint work with Anne Thomas. (Received September 15, 2013)

1096-20-1502 **David C Meyer*** (david-c-meyer@uiowa.edu), 422 Brown St. Apt. 4, Iowa City, IA 52245. *Universal deformation rings and fusion.*

Let Γ be a finite group, and 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 $\alpha : R(\Gamma, V) \to R$. The structure of $R(\Gamma, V)$ is closely related to the cohomology groups $\mathrm{H}^i(\Gamma, \mathrm{Hom}_{\mathbb{F}_p}(V, V))$ for $i = 1, 2$. In this talk, we consider the case when Γ is an extension of a group G with order relatively prime to p, by an elementary abelian p-group N. We discuss $\mathrm{H}^i(\Gamma, \mathrm{Hom}_{\mathbb{F}_p}(V, V))$ for $i = 1, 2$ and the extent to which $R(\Gamma, V)$ can see the fusion of N in Γ. (Received September 16, 2013)

1096-20-1511 **Sebastian W. Hensel*** (hensel@math.uchicago.edu), The University of Chicago, Department of Mathematics, 5734 South University Avenue, Chicago, IL 60637-1546, and **Piotr Przytycki** and **Richard C. H. Webb**. *Uniform hyperbolicity for arc and curve graphs.*

In this talk, I will describe unicorn paths in arc and curve graphs and show that they form 1-slim triangles. From this, one can deduce that arc graphs are 7-hyperbolic (the complete proof will fit in the 20 minutes). Considering the same paths in the arc and curve graph, the same methods also show that all curve graphs are 17-hyperbolic, including closed surfaces. (Received September 16, 2013)

1096-20-1637 **Luise-Charlotte Kappe*** (menger@math.binghamton.edu), Department of Mathematical Sciences, Binghamton, NY 13902-6000, and **Daniela Nikolova-Popova** and **Eric Swartz**. *On the covering number of some small symmetric groups and some sporadic simple groups.*

Every group G with a finite non-cyclic homomorphic image is a union of finitely many proper subgroups. The minimal number of subgroups needed to cover G is called the covering number of G, denoted by $\sigma(G)$. Tomkinson showed that for a solvable group G, $\sigma(G) = p^k + 1$, where p is a prime, and he suggested the investigation of the covering number for families of finite non-solvable groups.

For symmetric groups S_n Maroti showed that $\sigma(S_n) = 2^{n-1}$ if n is odd unless $n = 9$ and $\sigma(S_n) \leq 2^{n-2}$ if n is even. We show $\sigma(S_8) = 64$, $\sigma(S_9) = 256$ and $\sigma(S_{10}) = 221$. For the Mathieu group M_{12} we show $\sigma(M_{12}) = 208$ and improve estimates given by Holmes for some other sporadic simple groups. (Received September 16, 2013)

1096-20-1646 **Joseph P Brennan***, Department of Mathematical Sciences, Binghamton, NY 13905, and **Luise-Charlotte Kappe** and **Gabriela Mendoza**. *Variation on a Theme of I.D. MacDonald.* Preliminary report.

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. (Received September 16, 2013)

1096-20-1691 **Catherine A Buell*** (cbuell@bates.edu). *On maximal quasi $\mathbb{R}$-split tori invariant under an involution.*

Real symmetric spaces are of importance in many fields, but their main use has been in mathematics and physics. Symmetric k-varieties are a generalization of the real symmetric spaces to spaces defined over arbitrary fields. These spaces are formed from a group G, an involution of G, and the fixed point group of the involution.

The conjugacy classes of maximal k-split tori can be used to determine the orbit decomposition of minimal parabolic subgroups acting on a symmetric variety which is important to the representation theory of symmetric varieties. Commuting pairs and associated pairs of involutions classify the tori within the fixed point groups of the involutions. I'll discuss various characterizations for any k. For $k = \mathbb{R}$, I'll provide a classification of the representatives of maximal quasi $\mathbb{R}$-split tori. (Received September 16, 2013)

1096-20-1710 **Jay Zimmerman*** (jzimmerman@towson.edu) and **Coy L. May**. *Large odd order groups of fixed symmetric genus.* Preliminary report.

Let G be a finite group of odd order. The *symmetric genus* $\sigma(G)$ is the minimum genus of any Riemann surface on which G acts. Suppose that G acts on a Riemann surface of genus $g \geq 2$. If $|G| > 8(g-1)$, then $|G| = K(g-1)$, where K is 15, $\frac{21}{2}$, 9 or $\frac{33}{4}$. We call these four types of groups LO-1 through LO-4 groups, respectively. Previously, we have shown that there are infinite families of each type in a non-constructivist way. A number of new examples of such groups are constructed. In particular, nilpotent LO-3 groups was studied by Zomorrodian. We study metabelian LO-3 groups and obtain a number of results about their structure. Finally, the integers that occur as the symmetric genus of groups in these classes have density zero in the positive integers. (Received September 16, 2013)

1096-20-1717 **Tara C. Davis*** (tdavis@hpu.edu), 1164 Bishop Street, UB 210A, Honolulu, HI 96813, and **Alexander Yu. Olshanskii** (alexander.olshanskiy@vanderbilt.edu). *Relative Subgroup Growth and Subgroup Distortion.*

We study the relative growth of finitely generated subgroups in finitely generated groups, and the corresponding distortion function of the embeddings. We explore which functions are equivalent to the relative growth functions and distortion functions of finitely generated subgroups. We also study the connections between these two asymptotic invariants of group embeddings. We give conditions under which a length function on a finitely generated group can be extended to a length function on a larger group. (Received September 16, 2013)

1096-20-1738 **Keith M Jones*** (keith.jones@oneonta.edu), Department of Mathematics, CS & Stats, SUNY Oneonta, 108 Ravine Parkway, Oneonta, NY 13820. *Visual Boundaries for Diestel-Leader Graphs.*

One standard way to construct a visual boundary of a CAT(0) space is as a set of equivalence classes of geodesic rays. We extend this definition to a more general setting to construct the visual boundaries of Diestel-Leader graphs, some of which happen to be particularly useful Cayley graphs for lamplighter groups. We see that the visual boundary of $DL(q, q)$, the Diestel-Leader graph corresponding to the lamplighter group L_q is satisfies the separation axiom T_1, but is not Hausdorff. We show that for $d > 2$, the visual boundary of the Diestel-Leader graph $DL_d(q)$ (constructed from d $q+1$ valent trees) has the indiscrete topology. (Received September 16, 2013)

1096-20-1936 **Jingyin Huang*** (jingyin@cims.nyu.edu), Courant Institute of Mathematical Sciences, New York University, 251 Mercer Street, New York, NY 10012. *Quasi-isometry rigidity for right-angled Artin group with finite outer automorphism group.* Preliminary report.

Let G_1 and G_2 be two right-angled Artin groups and assume $Out(G_1)$ is finite, we show one can tell whether G_1 is quasi-isometric to G_2 by looking at their Tits boundaries. In particular, if $Out(G_2)$ is also finite, then G_1 and G_2 are quasi-isometric iff they are isomorphic. (Received September 16, 2013)

1096-20-1951 **Vladimir V Chaynikov***, chayn1v@cmich.edu. *Every Non-Elementary Hyperbolic Group Admits a Highly Transitive Action of Maximal Growth.*

We prove that every non-elementary hyperbolic group G acts highly transitively (i.e. k-transitively for all natural numbers k) on some infinite set X. Moreover the constructed action has maximal growth, finite kernel $E(G)$ (i.e. the maximal finite normal subgroup of G) and each orbit of action by every element $g \in G$ is finite.

As a side-product of our approach we prove that for a non-elementary hyperbolic group G and a quasiconvex subgroup of infinite index $H \leq G$ there exists $g \in G$ such that $\langle H, g\rangle$ is quasiconvex of infinite index and is isomorphic to $H * \langle g\rangle$ if and only if $H \cap E(G) = \{e\}$. (Received September 16, 2013)

1096-20-2165 **Jennifer C. H. Wilson*** (wilsonj@math.uchicago.edu), University of Chicago, Department of Mathematics, 5734 S University Avenue, Chicago, IL 60637. *Stability phenomena for sequences of representations of the classical Weyl groups.*

Over the past three years, Church, Ellenberg, Farb, and Nagpal developed the theory of FI-modules for studying sequences of representations of the symmetric groups. I will outline their work, and explain how it adapts to sequences of representations of any family of classical Weyl groups. We can use this theory to describe the structure of a variety of sequences coming from algebra, geometry, and topology, including the cohomology rings of several families of groups related to the pure braid groups. (Received September 17, 2013)

1096-20-2211 **Brian Gapinski*** (bgapinski@gmail.com), 3920 Breaking Dawn St, Colorado Springs, CO 80925, and **Tyler Weber** (webert2575@my.uwstout.edu), 1612 14th Avenue East, Menomonie, WI 54751. *Strong depth and quasi-geodesics in finitely generated groups.*

A "dead end" in the Cayley Graph of a finitely generated group is an element g beyond which no geodesic ray issuing from the identity can be extended. The structure of dead ends and of geodesics in finitely generated groups is known to depend strongly on the generating set chosen. In this talk, we focus on the so-called "strong dead end depth" of group elements and on quasi-geodesics. We show that these two objects are comparatively well-behaved. In particular, we show that the ratio of strong depth to word length is bounded above by 1/2 in every finitely generated group and that every finitely generated group possess a quasi-geodesic completeness property ensuring, for each group element, the existence of an infinite quasi-geodesic ray issuing from the identity and passing through that element. (Received September 17, 2013)

1096-20-2223 **Yanxi Liu*** (yanxi@cse.psu.edu). *Computational Symmetry for Automatic Pattern Discovery.*

Symmetry is an essential mathematical concept, as well as a ubiquitous observable phenomenon in nature, science and art. Either by evolution or by design, symmetry imparts an efficient coding that makes it universally appealing. Recognition of symmetry and regularity is the first step towards capturing the essential structure of a real world problem while minimizing computational redundancy. Automatic symmetry detection from real world (digital) data turns out to be a surprisingly challenging problem that has puzzled researchers in machine intelligence, computer vision, robotics, and computer graphics for the past four decades. Recognizing the fundamental relevance and potential power due its principled root that computational symmetry affords, we explore a formal and computational characterization of real world symmetry using a group theoretical model. In this talk, I summarize the theoretical background on crystallographic groups, and illustrate few recent results of applications of computational symmetry in computer vision. (Received September 17, 2013)

1096-20-2406 **Corey M. Manack*** (cmanack@amherst.edu), Amherst, MA 01002. *Character Estimates for Adjoint Simple Lie Groups.*

Call a compact, connected, simple Lie group G *adjoint simple* if it has trivial center. Let $C \subset G$ be a nontrivial conjugacy class, $e \in G$ the identity element of G. We prove the existence of an $N \in \mathbb{N}$, depending on G but not C, such that e lies in the interior of C^n for all $n \geq N$. We then prove that a disk $D \subset \mathbb{C}$ of radius less than 1, contained in the unit disk D_1 and tangent to D_1 at $z = 1$, contains the image of every normalized character $\chi(e)^{-1}\chi$ of G. (Received September 17, 2013)

1096-20-2420 **Nathan A Corwin*** (nacorwin@math.rutgers.edu), Department of Mathematics - Hill Center, Rutgers, The State University of New Jersey, 110 Frelinghuysen Rd., Piscataway, NJ 08854-8019. *A short proof of a theorem of Claas Roever.* Preliminary report.

Richard J. Thompson's group V was first discovered in 1965. It is one of the first two known examples of a finitely generated infinite simple group. The understanding of its subgroups has been of interest since. An interesting property of V is that it contains every finite group as a subgroup. One of the many results in Class Roever's dissertation in 1999 is that Richard J. Thompson's group V does not have any finitely generated infinite torsion subgroups. We use the topological dynamics of V acting on the cantor set to give a short proof of this result. (Received September 17, 2013)

1096-20-2517 **Jason Behrstock*** (jason.behrstock@lehman.cuny.edu) and **Cornelia Drutu**. *Higher dimensional filling and divergence functions for mapping class groups.*

We will discuss the higher dimensional filling and divergence functions for mapping class groups of surfaces. We will establish bounds for these families of functions and show they exhibit phase transitions at the rank (as measured by 3 genus+number of punctures-3); this phase transition is analogous to a corresponding result for symmetric spaces which results from the combined work of Brady–Farb, Hindawi, Leuzinger, and Wenger. (Received September 17, 2013)

1096-20-2543 **Karen Vogtmann*** (kvogtmann@gmail.com). *The geometry of Outer space.*

Outer space was introduced in the early 1980's as a tool for studying the group $Out(F_n)$ of outer automorphisms of a finitely-generated free group. It is a contractible space on which $Out(F_n)$ acts with finite stabilizers, and can be thought of as analogous to a symmetric space (with the action of a non-uniform lattice) or the Teichmüller space of a surface (with the action of the mapping class group of the surface). Much progress has been made on understanding the topology of Outer space and of its quotient by $Out(F_n)$, but its geometry was largely unexplored until recently. Now through the efforts of many people a metric theory is emerging, resulting in new information about $Out(F_n)$ as well as elegant new proofs of older results, and strengthening the analogy between the classical theories of symmetric spaces and Teichmuller spaces. I will describe the basics of this theory, then focus on some striking recent work of Bestvina-Feighn and Handel-Mosher, who use this new geometry to prove that certain simplicial complexes naturally associated to free groups have negative curvature in the sense of Gromov. (Received September 17, 2013)

1096-20-2593 **Gregory A. Kelsey*** (gregory.kelsey@trincoll.edu), Department of Mathematics, Trinity College, 300 Summit St., Hartford, CT 06106, and **Keith Jones**. *Boundaries of Lamplighter groups.*

The boundary of a CAT(0) space has a few equivalent definitions. Two of these definitions: the visual boundary and the horofunction boundary can be defined outside the CAT(0) setting, but are no longer equivalent. In this brief talk, we state these boundaries of the lamplighter groups with a particular generating set and describe how they can be viewed in the context of the lampstand model for these groups. (Received September 17, 2013)

1096-20-2725 **Michael Hull*** (mbhull@uic.edu). *Acylindrically hyperbolic groups.*

Recently, Osin defined the class of acylindrically hyperbolic groups, a generalization of hyperbolic and relatively hyperbolic groups which includes mapping class groups, outer automorphism groups of free groups, directly indecomposable non-cyclic RAAGs, as well as many other examples. we will discuss how some aspects of the theory of hyperbolic groups such as small cancellation theory and non-trivial bounded cohomology can be generalized to the class of acylindrically hyperbolic groups. (Received September 18, 2013)

1096-20-2789 **Arthur D. Grainger***, Morgan State University, Baltimore, MD. *On the structure of βS_J.*

Let J be infinite and let $I = \mathcal{P}_f(J)$. Define $S_J = \{(i, f) \mid i \in I,\ f : \mathcal{P}(i) \to \mathcal{P}(i)\}$. For (i, f), $(k, g) \in S_J$, define $f * g : \mathcal{P}(i \cup k) \to \mathcal{P}(i \cup k)$ as follows. For $x \in \mathcal{P}(i \cup k)$, let $(f * g)(x) = g(x)$, if $x = \varnothing$; let $(f * g)(x) = g(x \cap k)$, if $x \cap k \neq \varnothing$; let $f * g(x) = f(x)$, if $x \in \mathcal{P}(i \backslash k)$ and $x \neq \varnothing$. Define $(i, f) * (k, g) = (i \cup k, f * g)$. $(S_j, *)$ is a semigroup. We consider $(\beta S_J, \circledast)$, the *Stone–Čech* Compactification of the semigroup $(S_J, *)$. The collection $\{\beta_A(S_J) \mid A \in \mathcal{P}(J)\}$ is a partition of βS_J and the cardinality of $\beta_A(S_J)$ is $2^{2^{|J|}}$. (Received October 25, 2013)

22 ► Topological groups, Lie groups

1096-22-53 **Robert W. Benim*** (rwbenim@ncsu.edu), NCSU Mathematics Department, 2108 SAS Hall, Box 8205, Raleigh, NC 27695, **Aloysius Helminck** (loek@ncsu.edu), NCSU Mathematics Department, 2108 SAS Hall, Box 8205, Raleigh, NC 27695, **Chris Dometrius**, Forsyth Technical Community College, 2100 Silas Creek Parkway, Winston-Salem, NC 27103, and **Ling Wu**. *Inner Involutions of* $\mathrm{SO}(n, k, \beta)$*,* $(n > 2)$.

A first characterization of the isomorphism classes of k-involutions for any reductive algebraic groups defined over a perfect field was given in [Helminck 2000] using 3 invariants. In [Dometrius, Helminck, Wu] a classification of all involutions on $\mathrm{SL}(n, k)$ for k algebraically closed, the real numbers, the p-adic numbers or a finite field was provided. In this paper, we build on these results to develop a detailed characterization of the involutions of $\mathrm{SO}(n, k, \beta)$, where β is any non-degenerate symmetric bilinear form. We use these results to classify the isomorphy classes of inner-involutions of $\mathrm{SO}(n, k, \beta)$ where k is any field not of characteristic 2 or 3, and for some β where k is characteristic 3. (Received June 25, 2013)

1096-22-132 **Paul Frank Baum*** (baum@math.psu.edu), Department of Mathematics, McAllister Building, Pennsylvania State University, University Park, PA 16802. *Geometric structure and the local Langlands conjecture.*

Let G be a connected split reductive p-adic group. Examples are $GL(n, F), SL(n, F), SO(n, F), Sp(2n, F), PGL(n, F)$ where n can be any positive integer and F can be any finite extension of the field Q_p of p-adic numbers. The smooth dual of G is the set of equivalence classes of smooth irreducible representations of G. The representations are on vector spaces over C. In the smooth dual there are subsets known as the Bernstein components, and the smooth dual is the disjoint union of the Bernstein components. This talk will explain a conjecture due to Aubert-Baum-Plymen-Solleveld (ABPS) which says that each Bernstein component is a complex affine variety. These affine varieties are explicitly identified as certain extended quotients. The infinitesimal character of Bernstein and the L-packets which appear in the local Langlands conjecture are then described from this point of view. Granted a mild restriction on the residual characteristic of the field F over which G is defined, ABPS has been proved for any Bernstein component in the principal series of G. A corollary is that the local Langlands

conjecture is valid throughout the principal series of G.
The above is joint work with Anne-Marie Aubert, Roger Plymen, and Maarten Solleveld. (Received August 04, 2013)

1096-22-336 **Aaron Wood*** (woodad@missouri.edu), 202 Mathematical Sciences Building, University of Missouri, Columbia, MO 65211. *Hecke algebra correspondence for the 2-adic metaplectic group.*

A minimal type of the Weil representation of a two-fold central extension of $\mathrm{Sp}_{2n}(\mathbb{Q}_2)$ is used to produce a Hecke algebra which is isomorphic to the Iwahori-Hecke algebra of a split orthogonal group of type B_n. In addition to parameterizing certain metaplectic representations, this correspondence gives a natural way to transfer the Plancherel measure of the split orthogonal group to the metaplectic group. (Received August 28, 2013)

1096-22-971 **Jeffrey Adler*** (jadler@american.edu) and **Joshua Lansky**. *The dual of a reductive algebraic group.* Preliminary report.

Let k be a field, and let G be a reductive algebraic k-group. If either k or the absolute root system of G satisfies certain conditions, then we construct a k-group G^* that is dual to G in a precise sense. For example, the absolute root data of G and G^* are dual to each other, and once a single choice has been made, there is a natural bijection between the set of stable conjugacy classes of maximal k-tori in G and the set of those in G^*. (Received September 11, 2013)

1096-22-1244 **Christian Zorn*** (christian.zorn79@gmail.com), 9330 Rock Ripple Lane, Laurel, MD 20723. *Building Toward a "Twisted" Theta Correspondence.* Preliminary report.

The local theta lift over a p-adic field takes a pair of reductive groups $G := \mathbf{G}(F)$ and $G' = \mathbf{G}'(F)$ (with F a p-adic field) along with a symplectic vector space V over F for which $G \times G' \subset H := \mathrm{Sp}(V)$. There exists covering groups $\widetilde{G}$, $\widetilde{G}'$, and $\widetilde{H}$ and a representation ω of $\widetilde{H}$ so that its restriction to $\widetilde{G} \times \widetilde{G}'$ decomposes "nicely". Representations $\pi \boxtimes \pi'$ appearing in this restriction are called *theta lifts* of each other.

In our talk, we discuss some results regarding theta lifts when G is a symplectic group and G' is an orthogonal group for an odd-dimensional orthogonal space. Namely, we aim to sketch a proof of the famous *theta dichotomy conjecture*. The proof relies heavily on the Rankin-Selberg-type doubling integral of Piatetski-Shapiro and Rallis. From there, We will introduce on-going research that defines the "twisted" doubling integral and attempt to compute their L-functions as well as interpret them in the theta correspondence framework. (Received September 13, 2013)

1096-22-1463 **Amanda Harsy Ramsay*** (aharsy@iupui.edu), 15577 Outside Trail, Noblesville, IN 46060. *The Amenable Actions of Locally Compact Groups.* Preliminary report.

A version of Yu's Property A in the case of locally compact groups is introduced. We will examine amenable actions of locally compact groups on compact spaces and their cohomological equivalence. A class of non-amenable, non-discrete groups that act on compact spaces amenably will also be discussed. (Received September 15, 2013)

1096-22-1495 **Alissa S. Crans*** (acrans@lmu.edu), **Jozef Przytycki** and **Krzysztof Putyra**. *Torsion in One-term Distributive Homology.*

The one-term distributive homology was introduced by J.H.Przytycki as an atomic replacement of rack and quandle homology, which was first introduced and developed by R.Fenn, C.Rourke and B.Sanderson, and J.S.Carter, S.Kamada and M.Saito. This homology was initially suspected to be torsion-free, but we show in this paper that the one-term homology of a finite spindle can have torsion. We carefully analyze spindles of block decomposition of type (n,1) and introduce various techniques to compute their homology precisely. In addition, we show that any finite group can appear as the torsion subgroup of the first homology of some finite spindle. Finally, we show that if a shelf satisfies a certain, rather general, condition then the one-term homology is trivial. (Received September 16, 2013)

1096-22-1722 **Jeffrey Hakim*** (jhakim@american.edu), Department of Mathematics and Statistics, American University, Washington, DC 20016, and **Omer Offen**. *Local Converse Theorems and Symmetric Spaces.* Preliminary report.

We discuss local converse theorems and their analogues for symmetric spaces over p-adic fields. Classical local converse theorems for GL(n) give criteria for the equivalence of two generic representations in terms of their Rankin-Selberg gamma factors with respect to twists by representations of GL(m) for m < n. For symmetric spaces, the natural analogue is a gamma factor criterion that implies that a representation is distinguished with respect to the symmetric space. We discuss our latest results on such local converse theorems. (Received September 16, 2013)

1096-22-1773 **Michael Fitzpatrick*** (michael-c-fitzpatrick@uiowa.edu), Department of Mathematics, 14 MacLean Hall, University of Iowa, Iowa City, IA 52242-1419, and **Charles Frohman** (charles-frohman@uiowa.edu), Department of Mathematics, 14 MacLean Hall, University of Iowa, Iowa City, IA 52242-1419. .

There are continuous families of representations of the braid group coming from the universal R-matrix of $U_q(sl_2)$ acting on invariant subspaces of tensor products of weight spaces. These representations break down as you approach certain roots of unity because the formula for the R-matrix has poles. We analyze the projective limit and see that these families limit to representations coming from evaluation of the Burau representation. This allows us to construct normalized limits of values of colored Jones polynomials of links converging to values of the Alexander polynomial.
(Received September 16, 2013)

1096-22-1810 **Brendan Kelly*** (kelly@math.utah.edu). *Finiteness Properties of Arithmetic Groups.*
A group G can fail to be FP_n but at the same time $H^n(G;\mathbb{Q})$ can be finite dimensional. The group $\mathbf{SL_n}(\mathbb{Z}[t])$ is not FP_n. It is an open question if $H^n(\mathbf{SL_n}(\mathbb{Z}[t]);\mathbb{Q})$ is finite dimensional. This talk will present recent work on answering this question by showing a family of subgroups of $\mathbf{SL_n}(\mathbb{Z}[t])$ where the cohomology is infinite dimensional. The primary technique is studying the action of $\mathbf{SL_n}(\mathbb{Z}[t])$ on the building for $\mathbf{SL_n}(\mathbb{Q}((t^{-1})))$. This work is joint with Morgan Cesa. (Received September 16, 2013)

1096-22-1850 **Thomas L. Madsen*** (thomas.l.madsen-1@ou.edu). *Types and covers for some quaternionic hermitian groups.*
The question of when and how parabolically induced representations decompose is central in the representation theory of p-adic groups. I will outline how the method of types and covers can be used to study this question. The method is purely local and can yield detailed information in good circumstances. In particular, I will discuss a class of examples in the case of quaternionic hermitian groups where the method gives explicit concrete results.
(Received September 16, 2013)

1096-22-1944 **Kimball Martin*** (kmartin@math.ou.edu), Department of Mathematics, University of Oklahoma, Norman, OK 73019. *The Ballad of Reading Guo.*
We give a reading of the ballad The Ballad of Reading Guo. (Received September 16, 2013)

1096-22-1979 **Kwangho Choiy** and **David Goldberg*** (goldberg@math.purdue.edu), Department of Mathematics, Purdue University, 150 N. University St, West Lafayette, IN 47907. *R–groups and reducibility for inner forms of classical groups.*
We discuss the transfer of Plancherel measures for parabolic subgroups of classical groups. For an irreducible discrete series, σ, of some Levi subgroup, M of a connected reductive quasi-split group, G, the associated rank one Plancherel measures determines the Knapp-Stein R–group. This R–group, $R(\sigma)$, along with a 2–cocycle arising from standard intertwining operators, determines the commuting algebra of the induced representation, and thus gives the reducibility structure of this induced representation. On the other hand, if G' is an inner form of a quasi-split classical group G, and if M' is a Levi subgroup of G', then M' is an inner form of a Levi subgroup M of G. If $\varphi : W'_F \to {}^LM$ is a parameter for an L–packet $\Pi_\varphi(M)$, then there is a corresponding L–packet $\Pi_\varphi(M')$. We show for every $\sigma \in \Pi_\varphi(M)$ and $\sigma' \in \Pi_\varphi(M')$, we have $R_G(\sigma) \simeq R_{G'}(\sigma')$. Thus, the reducibility structure of induced representations transfers as well. (Received September 17, 2013)

1096-22-2348 **Jeffrey Adams*** (jda@math.umd.edu), Dept. of Mathematics, University of Maryland, College Park, MD 20742. *Galois cohomology of real groups.* Preliminary report.
The classification of real forms of a complex reductive group is a problem in Galois cohomology. On the other hand, Cartan's theory of real forms states the classification in terms holomorphic involutions. It turns out that this is a special case of an identity of two kinds of cohomology.

Kneser's theorem says that if G is semisimple and simply connected over a p-adic field then $H^1(\Gamma, G) = 1$. The fact that this is false over the reals has ramifications in the Langlands program. As an application of the cohomology result we compute $H^(\Gamma, G)$ in the real case. (Received September 17, 2013)

1096-22-2358 **David C Manderscheid*** (manderscheid.1@osu.edu), Executive Dean of Arts and Sciences, 186 University Hall, 230 North Oval Mall, Columbus, OH 43210. *Using types and lattice models to relate theta-correspondences.*

The Weil representation can be used to parametrize representations of one group in terms of already known representations of another group using Howe's theory theta-correspondences. In the p-adic case one can also construct representations using the theory of types. The theory of lattice models of the Weil representation can be used to explicitly realize the representations attached to groups in theta-correspondences via types as has been illustrated, for example, in my work over the years. In this talk I will discuss how my techniques can also be used to study the relation between various theta-correspondences. I will illustrate this in the case of quadratic base change for SL(2). (Received September 17, 2013)

1096-22-2658 **Joshua M. Lansky*** (lansky@american.edu), Department of Mathematics and Statistics, American University, 4400 Massachusetts Ave., N.W., Washington, DC 20016-8050, and **Jeffrey D. Adler** (jadler@american.edu), Department of Mathematics and Statistics, American University, 4400 Massachusetts Avenue, N.W., Washington, DC 20016-8050. *Explicit Liftings of Representations of Finite Reductive Groups.* Preliminary report.

Let $\tilde{G}$ be a connected reductive group defined over a field k, Γ a group of k-automorphisms of $\tilde{G}$, and G the connected group of Γ-fixed points in $\tilde{G}$. We construct a lifting of semisimple conjugacy classes from the dual group G^* to $\tilde{G}^*$ and present certain properties of the lifting which make it possible to compute it more explicitly. This lifting is conjectured to relate the K-types of representations of an unramified p-adic group and those of their base change lifts over tame extensions. (Received September 17, 2013)

26 ► Real functions

1096-26-24 **George A Anastassiou*** (ganastss@memphis.edu). *The Reduction Method in Fractional Calculus and Fractional Ostrowski type inequalities.*

Here we study generalised fractional integrals and fractional derivatives. We present the reduction method of Fractional Calculus and we reduce them to basic fractional integrals and fractional derivatives. We give a series of generalised Ostrowski type fractional inequalities involving s–convexity. We apply all of the above to Hadamard and Erdélyi-Kober fractional integrals and fractional derivatives. We produce also important generalised fractional Taylor formulae. (Received May 23, 2013)

1096-26-25 **George A Anastassiou*** (ganastss@memphis.edu). *Generalised fractional Hermite-Hadamard Inequalities involving m-convexity and (s,m)-convexity.*

Here we present generalised fractional Hermite-Hadamard type inequalities involving m-convexity and (s,m)-convexity. These inequalities are with respect to generalised Riemann-Liouville fractional integrals. Our work is motivated by and expands recent work of Zhang and Wang to the greatest generality and all possible directions. (Received May 23, 2013)

1096-26-26 **George A Anastassiou*** (ganastss@memphis.edu). *General Grüss and Ostrowski type inequalities involving s-convexity.*

Using the well known representation formula for functions due to Fink, we establish a series of general Grüss and Ostrowski type inequalities involving s-convexity and s-concavity in the second sense, acting to all possible directions. (Received May 23, 2013)

1096-26-739 **Paul Eloe*** (peloe1@udayton.edu) and **Jeffrey T. Neugebauer**. *Application of μ_0-positive operators to boundary value problems for fractional differential equations.*

Let $\alpha > 1$. The theory of u_0-positive operators with respect to a cone in a Banach space is applied to boundary value problems for fractional linear differential equations of the form $D_0^\alpha u + \lambda p(t)u = 0, 0 < t < 1$, where $D_0^\alpha u$ denotes a Riemann Liouville fractional derivative. As usual, a Green's function, $G(t,s)$, is constructed and the operator

$$Mu = \int_0^1 G(t,s)\lambda p(s)u(s)ds$$

is analyzed. Of interest is the construction of a Banach space and a cone such that M maps the cone into the interior of the cone. (Received September 09, 2013)

1096-26-866 **Hernán Castro**, **Juan Dávila** and **Hui Wang*** (huiwang@math.rutgers.edu), Department of Mathematics, Rutgers University, 110 Frelinghuysen Road, Piscataway, NJ 08854. *A Hardy type inequality for $W_0^{m,1}$ functions with $m \geq 2$.*

It is well-known that the classical Hardy's inequality holds only for $p > 1$. In other words, Hardy's inequality fails for $W_0^{1,1}$ functions. However, if we allow one more derivative, i.e., consider $W_0^{2,1}$ functions, we will be able to establish a Hardy type inequality. In this talk, we will discuss both the one dimensional case and the higher dimensional case, and will see the differences between them. (Received September 10, 2013)

1096-26-2340 **Yuval Peres***, Microsoft Research, 1 Microsoft Way, Redmond, WA 98052. *Dimension of fractional Brownian motion with variable drift.*

Let X be a fractional Brownian motion in $\mathbf{R}^d$. For any Borel function $f : [0,1] \to \mathbf{R}^d$, we express the Hausdorff dimension of the image and the graph of $X + f$ in terms of f. This is new even for the case of Brownian motion and continuous f, where it was known that this dimension is almost surely constant. The expression involves an adaptation of the parabolic dimension previously used by Taylor and Watson to characterize polarity for the heat equation. In the case when the graph of f is a self-affine McMullen-Bedford carpet, we obtain an explicit formula for the dimension of the graph of $X + f$ in terms of the generating pattern. In particular, we show that it is strictly bigger than the maximum of the Hausdorff dimension of the graph of f and that of X. Despite the random perturbation, the Minkowski and Hausdorff dimension of the graph of $X + f$ can disagree. (Joint work with Perla Sousi, Cambridge, UK) (Received September 17, 2013)

1096-26-2360 **Heather A Van Dyke*** (hvandyke@smcm.edu), St. Mary's College of Maryland, 18952 E Fisher Road, Schaefer Hall, St. Mary's City, MD 20686-3001, and **Kevin R Vixie** and **Thomas J Asaki**. *Monotonicity in Higher Dimensions.*

In search of a meaningful 2-dimensional analog to monotonicity, we introduce two new definitions and give examples of and dis- cuss the relationship between these definitions and others that we found in the literature. (Received September 17, 2013)

28 ► Measure and integration

1096-28-964 **Andres del Junco***, deljunco@math.toronto.edu. *A measure-theoretic version of the divergence theorem.* Preliminary report.

(Joint work with Mustafa Akcoglu) We prove a measure-theoretic generalization of the Divergence Theorem. The result is not new but we hope to make it more accessible by giving a proof which uses only the standard tools of basic measure theory: the theorems of Egoroff, Lusin, Fubini, Radon-Nikodym and the one-dimensional Lebesgue differentiation theorem. We start by giving an abstract definition of a Gauss region in $\mathbb{R}^d$, equivalent to the notion of a BV region in geometric measure theory. We then define the boundary, boundary measure and outward normal in a purely measure-theoretic manner and obtain the Divergence theorem in terms of these concepts. Finally we show that the boundary is approximately C^1 and that the boundary measure and normal correspond to the usual geometric concepts. An interesting feature here is that this approach mimics the standard "proofs" of the Divergence Theorem found in elementary calculus texts, for regions bounded above and below by graphs of functions. (Received September 11, 2013)

30 ► Functions of a complex variable

1096-30-186 **John A. Emanuello*** (jemanuel@math.fsu.edu), The Florida State University, Department of Mathematics, 1017 Academic Way, Tallahassee, FL 32306-4510. *Projective Compactification of $\mathbb{R}^{1,1}$ and its Möbius Geometry.*

We examine the semi-Riemannian manifold $\mathbb{R}^{1,1}$, which is realized as the split complex plane, and its conformal compactifcation as an analogue of the complex plane and the Riemann sphere. We also consider conformal maps on the compactifcation and study some of their basic properties. (Received August 14, 2013)

1096-30-306 **Jeanine L. Myers*** (jeanine.myers@uafs.edu), 5210 Grand Ave., P.O. Box 3649, Fort Smith, AR 72913-3649. *The Effect of Symmetry on the Riemann Map.*

The Riemann mapping theorem guarantees the existence of a conformal mapping or Riemann map in the complex plane from the open unit disk onto an open simply-connected domain, which is not all of $\mathbb{C}$. Although its existence is guaranteed, the Riemann map is rarely known except for special domains like half-planes, strips, etc. Therefore, any information we can determine about the Riemann map for any class of domains is interesting and useful.

This research investigates how symmetry affects the Riemann map. In particular, we define domains with symmetries called Rectangular Domains or RDs. The Riemann map of an RD has real-valued coefficients, as opposed to complex-valued, and therefore we can determine the sign of the coefficients of the Taylor series about the origin of the Riemann map, $f(z)$, from the unit disk onto RDs determined by $f(0) = 0$ and $f'(0) > 0$. We focus on the form of the Riemann map for specific RD polygons. (Received August 27, 2013)

1096-30-327 **Claudio Meneses-Torres*** (claudio@math.sunysb.edu), Mathematics Department, Stony Brook University, Stony Brook, NY 11794, and **Leon A. Takhtajan**. *WZNW action and Kähler potentials on the moduli space of parabolic bundles over $\mathbb{P}^1$*. Preliminary report.

The moduli problem of stable parabolic bundles over the Riemann sphere can be interpreted from a complex analytic perspective. This allows us to introduce canonical complex coordinates on the moduli space (analogous to the Bers' coordinates on Teichmüller spaces) and a suitable analog of uniformization. The identification of the tangent space at a point with a certain space of automorphic forms leads to the introduction of the parabolic Narasimhan-Atiyah-Bott metric on the Moduli space, which is analogous to the Weil-Petersson metric.

Secondly, for each stable parabolic bundle, a regularized WZNW action functional is defined on the space of singular Hermitian metrics with prescribed asymptotics at a finite set of points in the sphere. We prove that these functionals evaluated at their extrema give rise to a function on the moduli space that is a Kähler potential for the parabolic Narasimhan-Atiyah-Bott metric over the restriction to a certain analytic open subset. (Received August 28, 2013)

1096-30-436 **Timothy J Ferguson*** (timothy.j.ferguson@vanderbilt.edu), Department of Mathematics, 1326 Stevenson Center, Vanderbilt University, Nashville, TN 37240. *Regularity of Extremal Functions in Weighted Bergman and Fock Type Spaces.*

We discuss the regularity of extremal functions in certain weighted Bergman and Fock type spaces. Given an appropriate analytic function k, the corresponding extremal function is the function with unit norm maximizing $\mathrm{Re} \int_\Omega f(z)\overline{k(z)}\,\nu(z)\,dA(z)$ over all functions f of unit norm, where ν is the weight function and Ω is the domain of the functions in the space. We consider the case where $\nu(z)$ is a decreasing radial function satisfying some additional assumptions, and where Ω is either a disc centered at the origin or the entire complex plane. We show that if k grows slowly in a certain sense, then f must grow slowly in a related sense. (Received September 03, 2013)

1096-30-683 **Yunping Jiang**, **Sudeb Mitra**, **Hiroshige Shiga** and **Zhe Wang*** (wangzhecuny@gmail.com), 4265 Kissena BLVD, APT 127, Flushing, NY 11355. *An Example of Quasiconformal Motion.*

I will talk about cross ratio and quasiconformal motion. A counter example of a Sullivan and Thurston's result about quasiconformal motion will be constructed. The extension theorem of quasiconformal motion and Earle-Gardienr-Lakic's equivalence theorem of cross ratio norm and Teichmuller norm will also be discussed in this talk. This is a joint work with Yunping Jiang, Sudeb Mitra, Hiroshige Shiga. (Received September 09, 2013)

1096-30-747 **Nadya Askaripour*** (askarina@ucmail.uc.edu), Department of Mathematical sciences, French Hall West, 2815 Commons Way, University of Cincinnati, Cincinnati, OH 45221. *Poincare series map and k-differentials on Riemann surfaces.*

A k-differential on a Riemann surface R is a section of the cotangent bundle on R tensured k-times by itself. A k-differential can be seen as automorphic form of weight k also. Quadratic differentials (case k=2) are special, because of their relation to Teichmuller theory. Poincare series is a classic technique to construct k-differentials. It is linear, bounded and surjective operator. Poincare series have some applications in studying of k-differentials on Riemann surfaces. In this talk I will review some facts about k-differentials and Poincare series map, and also I will present some new results about them. (Received September 09, 2013)

1096-30-819 **Elizabeth L. Fitzgibbon*** (lizfitz@bu.edu), Department of Mathematics & Statistics, 111 Cummington Mall, Boston, MA 02215, and **Stefano Silvestri**. *Rational Maps: Julia sets from accessible Mandelbrot sets are not homeomorphic.*

We investigate Julia sets of singularly perturbed complex rational maps of the form $F_\lambda(z) = z^n + \frac{\lambda}{z^d}$. For the case $n = d = 2$, we develop a topological invariant to show that two maps drawn from main cardioids of distinct accessible Mandelbrot sets containing a cycle of period m do not have homeomorphic Julia sets, unless these cardioids are complex conjugates of one another. We then consider cases with $n = d > 2$. (Received September 10, 2013)

1096-30-980 **Yunping Jiang*** (yunping.jiang@qc.cuny.edu), Queens College, CUNY and CUNY Graduate Center, and **Sudeb Mitra**, **Hiroshige Shiga** and **Zhe Wang**. *Universal Local Quasiconformal Motions.*

An important property in the theory of holomorphic motions is that there are universal holomorphic motions. In Zhe Wang's talk also in this session, he will prove that these universal holomorphic motions can not be universal in quasiconformal motions as defined in Sullivan and Thurston's paper. This disproved a claim in Sullivan and Thurston's paper. To fix this problem, we define a local quasiconformal motions and prove that these universal holomorphic motions are indeed universal in local quasiconformal motions. (Received September 11, 2013)

1096-30-1043 **Oleg Muzician*** (omuzician@bmccc.cuny.edu), 199 Chambers street, New York, NY 10007, and **Jun Hu**. *How the maximal dilatation of the Douady-Earle extension near the origin is controlled by the distortion of the boundary map on finitely many points.*

We study how the maximal dilatation of the Douady-Earle extension near the origin is controlled by the distortion of the boundary map on finitely many points. Consider the case with points evenly spread on the circle. Then the maximal dilatation of the extension in a neighborhood of the origin has an upper bound depending only on the cross-ration distortion of the boundary map on these points if and only if the number of points n is more than 4. Furthermore, the size of the neighborhood is universal for each n>4, in the sense that it depends only on the distortion. (Received September 12, 2013)

1096-30-1978 **George Csordas** and **Tamas Forgacs*** (tforgacs@math.hawaii.edu). *On multiplier sequences of the second kind.* Preliminary report.

In their 1914 paper Pólya and Schur introduced and completely characterized multiplier sequences of the first and second kind. Subsequent investigations have focused on multiplier sequences of the first kind for various polynomial bases other than the standard one. In this talk we discuss some basic properties of multiplier sequences of the second kind and present preliminary results regarding multiplier sequences of the second kind for bases other than the standard one. (Received September 17, 2013)

1096-30-2244 **Mohammed A. Qazi*** (qazima@aol.com), Dept. Of Mathematics, Tuskegee University, Tuskegee, AL 36088. *Complex-Valued Functions and the Mean Value Theorem.*

The mean value theorem for real-valued differentiable functions defined on an interval is one of the most fundamental results in Analysis. When it comes to complex-valued functions the theorem fails even if the function is differentiable throughout the complex plane. We illustrate this by means of examples and also present some results of a positive nature. (Received September 17, 2013)

1096-30-2352 **Brett Hafferkamp*** (brett.hafferkamp@ttu.edu). *Expected Values of the Conformal Radius.* Preliminary report.

This presentation examines problems on how randomness affects values involving the conformal radius. First, I look at two points contained in disjoint domains. When the points are distributed randomly in a known way, I seek to find an upper bound for the expected value of the product of the conformal radii without knowledge of the domains themselves. Some situations that will be presented are when the points are distributed **a)** uniformly in the unit disk; **b)** with the real parts and imaginary parts being independently and normally distributed. Second, I look at situations where the domain is known, the location of a point within the domain is not known, but it is distributed randomly in a known way. I seek to find exactly the expected value of the conformal radius. Of all domains with a fixed area I believe the disk maximizes this expected value. To that end, I develop a result on how this expected value changes under conformal maps and use the result on parameterized families of domains to provide evidence that supports this conjecture. (Received September 17, 2013)

31 ► Potential theory

1096-31-1053 **Willi Freeden*** (freeden@mathematik.uni-kl.de), Prof. Dr., 67653 Kaiserslautern, Palatinate, Germany. *Multiscale Regularization in Seismic Tomography.*

The aim of seismic tomography is to extract specific information about the composition and the disturbances of the bedrock about available data (seismograms), which arises from the scattering of seismic waves on boundary layers or from the conversion of certain wave types. An essential goal is to transfer the signal, which results from integration of the wave equation under the expectation, that designated properties of the rock like the velocity field can be interpreted from the transformed signal in a better way.

In this talk, based on the regularization of Green's functions (fundamental solutions), new wavelet techniques for a detailed band-pass filtering of (acoustic as well as elastic) seismic phenomena are formulated to get a local understanding and interpretability of scattered wavefield potentials. (Received September 12, 2013)

32 ► Several complex variables and analytic spaces

1096-32-742 **Clinton Cooper Zimmerman*** (`clintonzim@aol.com`), 16612 Sioux Lane, Gaithersburg, MD 20878. *Use of novel complex metrics in the derivation of the sum of paths transition function.* Preliminary report.

Consider a path defined by segments ABCD. Suppose segment AB had real length,BC had imaginary length and CD had real length so that a particle traveling over AB would travel a real distance X1 and a particle traveling over BC would travel an imaginary distance iX2 where X1 and X2 are real. This defines a grid, a path defined by alternating real and imaginary segments. Grids can be defined with large numbers of imaginary segments. Grids can be given a specific physical interpretation in quantum systems. The paper discusses general mathematical properties of grids such as segment swap which is the rearrangement of real segments on a grid. Parallel and serial annihilation which is the sequential or simultaneous removal of imaginary segments from a grid in a measurement process and the generation of paired or associated segments in a multi-grid system. The paper derives a general rule for calculating probabilities in any system parameterized by grids called the composition theorem and gives a result of fundamental importance by deriving the Feynman transition function used in quantum mechanics. (Received September 14, 2013)

1096-32-947 **Constanze Liaw*** (`constanze_liaw@baylor.edu`), Department of Mathematics, Baylor University, One Bear Place #97328, Waco, TX 76798, and **Catherine Beneteau**, **Alberto A. Condori**, **Daniel Seco** and **Alan A. Sola**. *Cyclic functions in Dirichlet type spaces over the bidisk.*

We study Dirichlet-type spaces of analytic functions in the unit bidisk, and their cyclic elements. These are the functions f for which there exists a sequence (p_n) of polynomials in two variables such that $\|p_n f - 1\| \to 0$ as $n \to \infty$. We obtain a number of conditions that imply cyclicity, and, by using results concerning Hilbert spaces of functions of one complex variable and comparisons between norms in one and two variables, we obtain sharp estimates on the best possible rate of decay of the norms $\|p_n f - 1\|$ for certain classes of functions.

We present a polynomial with no zeros on the bidisk that is not cyclic in a range of Dirichlet-type spaces (including the Dirichlet space). Since in one complex variable all analytically continuable functions with no zeros on the unit disk are cyclic, this exemplifies the contrast between cyclicity in one versus two complex variables. Further, we extend from the disk to the bidisk Brown and Shield's proof of the necessity of the capacity zero condition (replaced by an appropriate notion) for cyclic functions. (Received September 11, 2013)

1096-32-1088 **Victoria Mansfield** (`mansfieldv8842@my.uwstout.edu`), 3310 Hyacinth Ct., Green Bay, WI 54301, and **Michael McLaughlin*** (`mm136009@ohio.edu`), 8492 St. Rt. 9, Hanoverton, OH 44423. *Polarizations with Respect to Infinite Type Hypersurfaces.*

Real-analytic, real hypersurfaces are often studied with the aid of biholomorphic invariants. One such invariant, called a *polarization*, is attached to a real hypersurface and is defined by the hypersurface's defining function. We will present a study of polarizations with respect to infinite type real hypersurfaces (i.e., hypersurfaces containing complex submanifolds); specifically, we will present our examination of the size of these respective polarizations. (Received September 12, 2013)

1096-32-1391 **Jing Zhang*** (`jzhang@albany.edu`), 1400 Washington Avenue, ES110, Department of Mathematics and Statistics, Albany, NY 12222. *Stein open subsets with Analytic Complements in Compact Complex Spaces.*

Let Y be an open subset of a reduced compact complex space X such that $X - Y$ is support of an effective divisor D. If X is a surface and D is an effective Weil divisor, we give sufficient conditions so that Y is Stein. If X is of pure dimension $d \geq 1$ and $X - Y$ is support of an effective Cartier divisor D, we show that Y is Stein if Y contains no compact curves, $H^i(Y, \mathcal{O}_Y) = 0$, for all $i > 0$ and for every point $x_0 \in X - Y$, there is an $n \in \mathbb{N}$ such that $\Phi^{-1}_{|nD|}(\Phi_{|nD|}(x_0)) \cap Y$ is empty or has dimension 0, where $\Phi_{|nD|}$ is the map from X to the projective space defined by a basis of $H^0(X, \mathcal{O}_X(nD))$. (Received September 15, 2013)

1096-32-1725 **Brendon Kerr Ballenger***, Love Building, 1017 Academic Way, Tallahassee, FL 32306, and **Craig A Nolder**. *Boundary Values of Components of Monogenic Functions.*

In this paper, we study the components of monogenic functions, i.e. functions in the kernel of the Dirac Operator $D = \frac{\partial}{\partial x_0} + \sum_{i=1}^{n} \frac{\partial}{\partial x_i}$. Furthermore, we apply the characterization of the existence of non-tangential limits for harmonic functions in terms of their area integrals. It is a well-known fact that if u is a harmonic function in $\mathbb{R}^3_+$, then for almost all $x \in \mathbb{R}^2$, the area integral,

$$S(u)(x) = \left(\int_{\Gamma(x)} |\nabla u|^2 y^{1-n} dV \right)^{\frac{1}{2}} < \infty$$

if and only if u has a non-tangential limit at x. We generalize this result for the quaternionic case. That is, for monogenic functions $u \in \mathbb{R}^3_+$ of the form

$$u = u_0 + u_1 e_1 + u_2 e_2 + u_3 e_1 e_2,$$

u_0 and u_3 have non-tangential limits almost everywhere on $\mathbb{R}^2$ if and only if u_1 and u_2 have non-tangential limits almost everywhere on $\mathbb{R}^2$. (Received September 16, 2013)

1096-32-1879 **Joshua Isralowitz**, **Mishko Mitkovski*** (mmitkov@clemson.edu) and **Brett Wick**. *On some basic operator theoretic questions in Bergman-type spaces.*

I will introduce the concept of Bergman-type spaces which incorporates the Bergman and the Bargmann-Fock spaces as prime examples and give several criteria that imply boundedness and compactness of operators on these spaces. Most of these results can be viewed as "reproducing kernel thesis" statements. Namely, these results show that many crucial properties of a given operator can be deduced just by looking at its behavior on the reproducing kernels in the space. (Received September 16, 2013)

1096-32-2461 **Brian Pike*** (bpike@utsc.utoronto.ca), Dept. of Computer and Mathematical Sciences, University of Toronto, Scarborough, 1265 Military Trail, Toronto, Ontario M1C 1A4, Canada. *The number of irreducible components of a linear free divisor.*

A complex hypersurface germ $(D, 0)$ in $V = \mathbb{C}^n$ has a module $\mathrm{Der}(-\log D)$ consisting of *logarithmic vector fields*, germs of ambient holomorphic vector fields which are tangent to $(D, 0)$. Then D is called a *linear free divisor* if $\mathrm{Der}(-\log D)$ is a free module and moreover has a free basis consisting of *linear* vector fields (e.g., $3x\partial_y + 2z\partial_x$). Every linear free divisor has a representation $\rho : G \to \mathrm{GL}(V)$ of a linear algebraic group G of dimension n with the property that ρ has a Zariski open orbit $\Omega \subset V$, and Ω is the complement of D in V. We prove that D has $\dim(G/[G, G])$ irreducible components and describe the structure of such groups. There are corresponding results for the Lie algebra of G, and the Lie algebra of linear elements of $\mathrm{Der}(-\log D)$. (Received September 17, 2013)

1096-32-2472 **Stergios Antonakoudis*** (stergios@math.harvard.edu), 50 Follen St, Cambridge, MA 02138. *When does an analytic map from Teichmueller space to itself have a fixed point?*

Determining the existence of fixed points for analytic maps of Teichmueller space to itself plays a prominent role is the study of conformal geometry and dynamics. It serves as a framework for proving 'geometrization' theorems, an important example of which is Thurston's topological characterization of post-critically finite rational maps. In this talk we will address the question of existence of fixed points for analytic self-maps on complex domains and show that under some mild conditions on the geometry of the domain any analytic map with a bounded orbit must have a fixed point. This applies, in particular, to all finite dimensional Teichmueller spaces. (Received September 17, 2013)

1096-32-2492 **Jerry R. Muir, Jr.***, Department of Mathematics, University of Scranton, Scranton, PA 18510. *Two-Point Distortion Bounds for Biholomorphic Mappings of the Ball in $\mathbb{C}^n$.* Preliminary report.

Lower and upper two-point distortion bounds for families $\mathcal{F}$ of biholomorphic mappings on the unit ball $\mathbb{B}$ of $\mathbb{C}^n$ are given in terms of the (trace) order of the linear-invariant family generated by $\mathcal{F}$, bounds on ratios involving the derivative and Jacobian of the mappings in $\mathcal{F}$, and the Carathéodory distance on $\mathbb{B}$. (By two-point distortion bounds, we mean estimates on $\|f(b) - f(a)\|$ for $a, b \in \mathbb{B}$ and $f \in \mathcal{F}$.) This immediately results in growth bounds for such mappings. A contrast is drawn between these bounds and two-point distortion bounds in terms of the norm order of the generated linear-invariant family. (Received September 17, 2013)

1096-32-2656 **Alexander Brudnyi** (abrudnyi@ucalgary.ca) and **Damir Kinzebulatov*** (dkinzebu@fields.utoronto.ca). *Towards Oka-Cartan theory for algebras of holomorphic functions on coverings of Stein manifolds.*

We obtain the basic results of complex function theory within algebras of fibrewise bounded holomorphic functions on coverings of Stein manifolds (model example: Bohr's holomorphic almost periodic functions). Our approach is based on an analogue of Oka-Cartan theory for coherent sheaves on the maximal ideal spaces of these algebras – Stein-like topological spaces, similar in many ways to complex manifolds:

– they are locally foliated by complex manifolds,

– they are the inverse limits of complex manifolds of increasing dimensions,

– they contain complex manifolds as a dense subsets.

Our results include interpolation over complex submanifolds within the algebra, corona type theorems, properties of divisors, a 'holomorphic' Peter-Weyl theorem, Hartogs type theorems, characterization of the uniqueness sets. (Received September 17, 2013)

1096-32-2657 **Malgorzata Aneta Marciniak***, mmarcin@bgsu.edu. *Holomorphic extensions in toric varieties with additional structures.*

A problem of holomorphic extensions from a complement of non separating compact set appears to be one of the fundamental questions for the theory of several complex variables. Observed by Hartogs for $\mathbb{C}^n$ with $n \geq 2$ was partially resolved for some special cases that include toric surfaces. The main method involves gluing together local data, even if obtaining local extensions does not follow the usual Hartogs solution for $\mathbb{C}^n$. (Received September 17, 2013)

1096-32-2726 **Robert Jacobson*** (rljacobson@member.ams.org), One Old Ferry Road, Bristol, RI 02809. *Weighted Bergman Kernel Functions Associated to Meromorphic Functions.*

We present a technique for computing explicit, concrete formulas for the weighted Bergman kernel on a planar domain with weight the modulus squared of a meromorphic function in the case that the meromorphic function has a finite number of zeros on the domain and a concrete formula for the unweighted kernel is known. (Received September 18, 2013)

33 ► Special functions

1096-33-770 **Hajime Nagoya*** (nagoya.hajime@rikkyo.ac.jp), Nishi-Ikebukuro 3-34-1, Toshima-ku, Tokyo 1718501, Japan. *Schrödinger systems from hypergeometric integrals of Euler type.*

The Painlevé equations are written as Hamiltonian systems with polynomial Hamiltonians in canonical coordinates. Hence, their canonical quantization is naturally considered. We call Schrödinger equations as canonical quantization of the Painlevé equations, quantum Painlevé equations.

Hypergeometric solutions to the quantum Painlevé equations were given in [N, J. Math. Phys. 2011]. These hypergeometric solutions are polynomials in the canonical coordinate whose coefficients are hypergeometric integrals. For example, the hypergeometric integrals for the quantum sixth Painlevé equation are generalization of those for the Gauss hypergeometric equation.

In my talk, as an example, I explain that this hypergeometric integrals are not only solutions to the quantum sixth Painlevé equation, but also give the quantum sixth Painlevé equation itself. Generalizing the example above, we present a method of construction of Schrödinger systems from hypergeometric integrals of Euler type and give a conjecture that Schrödinger systems obtained from hypergeometric integrals of Euler type are quantization of isomonodromic systems related to the Fuchsian systems satisfied by the hypergeometric integrals. (Received September 10, 2013)

1096-33-875 **Masatoshi Noumi*** (noumi@math.kobe-u.ac.jp), Department of Mathematics, Kobe University, Rokko, Kobe, 657-8501. *Padé interpolation and hypergeometric series.* Preliminary report.

In this talk I will discuss a class of Padé interpolation problems for which the solutions can be expressed in terms of determinants of hypergeometric series. (Received September 10, 2013)

1096-33-1332 **Yoshiaki Goto*** (y-goto@math.sci.hokudai.ac.jp), Department of Mathematics, Hokkaido University, Kita 10, Nishi 8, Kita-Ku, Sapporo, Hokkaido 060-0810, Japan. *The monodromy representation of Lauricella's F_C.*

To study the monodromy representation of a system of hypergeometric differential equations, we investigate variation of twisted cycles (integral regions) along loops in the complement of the singular locus. For this approach, the intersection pairing defined on twisted homology groups are useful. We obtain the monodromy representation of Lauricella's hypergeometric function F_C, by using the twisted homology groups associated to an integral representation of Euler type.

In this talk, I would like to explain how the monodromy representation of F_C is expressed. (Received September 16, 2013)

1096-33-1780 **Jessica D. Stewart*** (jessica_stewart@baylor.edu), One Bear Place #97328, Waco, TX 76798-7328, and **Lance L. Littlejohn** and **Constanze Liaw**. *The Spectral Analysis of the Exceptional Jacobi Differential Expression for Extreme Parameter Choices.*

In 2009, Gómez-Ullate, Kamran, and Milson characterized all sequences of polynomials $\{p_n\}_{n=1}^{\infty}$, with $\deg p_n = n \geq 1$, that are eigenfunctions of a second-order differential equation and are orthogonal with respect to a positive Borel measure on the real line having finite moments of all orders. Up to a complex linear change of variable, the only such sequences are the X_1-Laguerre and the X_1-Jacobi polynomials. In this talk, I will discuss the X_1-Jacobi differential expression $\ell_{\alpha,\beta}$ for the extreme parameter choice of $\alpha = 0$ which corresponds to the non-classical Jacobi expression with $\alpha = -2$. The self-adjoint operator associated with $\ell_{\alpha,\beta}$ and these extreme parameter choices can be studied in two spaces—one of which falls into the classical Glazman, Krein, Naimark theory; the other applies the left-definite theory introduced by Littlejohn and Wellman. In each case, the operator will have a complete set of [orthogonal] eigenfunctions. (Received September 16, 2013)

34 ► Ordinary differential equations

1096-34-54 **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.
Positive solutions for a system of nonlocal fractional boundary value problems.

We investigate the existence of positive solutions for a system of nonlinear Riemann-Liouville fractional differential equations, subject to multipoint boundary conditions. (Received June 27, 2013)

1096-34-58 **Boniface Otieno Kwach*** (brokwach@yahoo.com), P. O. BOX 1580, KISUMU, KENYA, KISUMU, NYANZA 40100, Kenya. *Mathematical Model for Drug Therapy in Patients With Diabetes Mellitus.*

This study presents a new mathematical model for Drug Therapy in Patients with Diabetes Mellitus which includes external rate at which blood glucose, insulin and epinephrine is being increased in the form, $\dot{Y} = f_i(g, h, e) + r_i(t)$. The system has been analyzed and solved to provide the systems natural frequency, ω_0, which is the basic descriptor of saturation level of the drug. We establish that the resonance period for the final model, that is, $T_0 = 3.76912$ hrs, agrees well with the data for the existing insulin therapy, showing that the peak, which is the time period for insulin to be most effective in lowering blood sugar, is in the acceptable therapeutic range.
Mathematics Subject Classification: Primary 93A30; Secondary 91B74, 93C15, 92C50, 92C42
Keywords: Mathematical model, Linear system, Natural frequency (Received June 29, 2013)

1096-34-103 **Luke Edwards*** (lde5025@psu.edu) and **Benjamin Weidenaar** (bweidena@friars.providence.edu). *USING PSM TO STUDY DELAY DIFFERENTIAL EQUATIONS WITH CHAOS.*

The Power Series Method (PSM) which is similar to Automatic Differentiation (AD) uses Maclaurin polynomials and Cauchy products of polynomials to solve initial value (IV) ordinary differential equations (ODEs). There is extensive literature on the power of these two methods and their differences in solving IV ODEs. In this talk (paper) we use PSM (for the first time as far as we know) to solve delay differential equations (DDEs). We show how PSM has to be modified to handle delays and demonstrate the efficacy and robustness of the algorithm on some examples. In particular, we apply the PSM to the pursuit problem with and without delay and compare with other methods. We show that PSM preserves the properties of the pursuit problem more accurately. We discuss some of the known theory of chaos in DDEs. We demonstrate chaos for the pursuit problem through the time delay. (Received July 29, 2013)

1096-34-133 **Tracy Weyand*** (weyand.tracy@gmail.com) and **Gregory Berkolaiko**. *Stability of Eigenvalues of Quantum Graphs.*

We consider the eigenvalues of the magnetic Schrödinger operator on a quantum graph as functions of the magnetic potential. We establish a simple relation between the Morse index of the magnetic eigenvalue and the number of zeros of the corresponding non-magnetic eigenfunction. This highlights an intricate relationship between zeros of an eigenfunction and the stability of the corresponding eigenvalue under magnetic perturbation.

In particular, let $\{\sigma_j\}_{j=1}^{\beta}$ be a set of generators of the fundamental group of a quantum graph Γ. The eigenvalues of the magnetic Schrödinger operator may be considered as functions of the magnetic flux $\boldsymbol{\alpha} = (\alpha_1, \ldots, \alpha_\beta)$ where $A(x)$ is the magnetic potential on Γ and

$$\alpha_i = \oint_{\sigma_j} A(x)\, dx.$$

Let ψ be the n-th eigenfunction of the ordinary Schrödinger operator (no magnetic potential) and assume that ψ is non-zero on the vertices of Γ. Let ϕ denote the number of internal zeros of ψ on Γ. We demonstrate that $(0, \ldots, 0)$ is a non-degenerate critical point of $\lambda_n(\boldsymbol{\alpha})$ with Morse index equal to the nodal surplus of ψ, which is $\phi - (n-1)$. (Received September 13, 2013)

1096-34-237 **Takao Suzuki*** (suzuki@math.kindai.ac.jp), 3-4-1, Kowakae, Higashi-Osaka, 577-8502, Japan. *A q-analogue of the Drinfeld-Sokolov hierarchy of type A and q-Painlevé system.*

In this talk, we propose a q-analogue of the Drinfeld-Sokolov hierarchy of type A. Its similarity reduction implies a class of higher order q-Painlevé systems, which are generalizations of the q-Painlevé VI equation given by Jimbo and Sakai. We also discuss a relationship with q-Painlevé systems and the q-hypergeometric functions. (Received September 05, 2013)

1096-34-479 **Oyita Udiani**, **Noa Pinter-Wollman** and **Yun Kang*** (yun.kang@asu.edu), 6073 S. Backus Mall, Wanner 301G, Mesa, AZ 85212. *A simple model of foraging activity in colonies of seed harvester ants.*

We develop a compartmental model of foraging activity of social ants to explore the interplay among forager return rate, forager retirement rate, and the constraints on vestibule size. Our model assumes i) equilibrium resource dynamics; ii) forager return rates regulate overall foraging activity; and iii) there is a linkage between the timescales of forager activation based on interactions in the vestibule and forager availability based on indirect recruitment from the inner nest allow for flexible adjustment to variable foraging conditions. One of our interesting results reveals the possibility for bi-stability corresponding to all or nothing activity states which matches previous experimental observations by Gordon (2002) in red seed harvester colonies. In addition, we validate and parameterize the model with experiment data. The sensitivity indices of parameters defining the threshold forager return density are also provided. (Received September 04, 2013)

1096-34-498 **Nalini Joshi***, School of Mathematics and Statistics F07, The University of Sydney, NSW 2006, Australia. *Geometric Asymptotics of q-difference Painlevé equations.*

We study solutions of q-difference Painlevé equations in an asymptotic limit. The specific equation we consider is a q-difference version of the first Painlevé equation (qP1) associated with rational surface of type $A_7^{(1)}$. We show that there are four families of almost stationary solutions in the limit as the independent variable approaches infinity, deduce their formal series expansions and study their convergence.

In the divergent case, we show that there exist true analytic solutions asymptotic to such series in a domain that contains all q-iterates of a given initial domain. Our results show that the solution is unstable in the space of solutions. The method, while demonstrated for qP1, is also applicable to other q-difference Painlevé equations and we suggest that the corresponding unstable solutions, which we call quicksilver solutions, should also exist for these other equations. (Received September 04, 2013)

1096-34-546 **Avner Peleg*** (apeleg@buffalo.edu), Department of Mathematics, University at Buffalo, Buffalo, NY 14260. *Large-scale particle dynamics simulations for pulse propagation in broadband optical fiber communication networks.*

We present an efficient model for simulating and analyzing propagation of optical solitons in fiber optics communication networks with a large number of frequency channels. The model consists of a system of hybrid stochastic nonlinear ODEs for the pulse parameters (amplitude, group velocity, etc.), where coupling is due to inter-pulse interaction and stochasticity is due to bit-pattern randomness. The derivation of the model is based on the method of eigenmode expansion with the eigenmodes of the linear operator $\hat{L}$, describing small perturbations about the fundamental soliton of the nonlinear Schrödinger (NLS) equation. We will discuss the main challenges in carrying out large-scale simulations with the model, including compensation of average effects, which requires analysis of N-dimensional Lotka-Volterra models. We will then present the results of the simulations for the probability density functions of pulse parameters, the equal-distance two-time correlation functions, and the error probability (the bit-error-rate). Comparison of the simulations results with predictions of a simplified stochastic mean-field ODE model will also be presented. (Received September 05, 2013)

1096-34-559 **Zhivko S. Athanassov*** (zhivko@math.bas.bg), G. Bonchev Str. 8, 1113 Sofia, Bulgaria.
Periodic Solutions of Ordinary Differential Equations. Preliminary report.

We prove a fixed point theorem for a class of nonlinear operators encountered in ordinary differential equations. The theorem differs from the theorems of Tychonoff and Schauder in that the operators in question do not need to act on a convex set. The proof depends on the Tychonoff fixed point theorem and a result of Blackwell. The theorem is then applied to prove the existence of periodic solutions of a class of ordinary differential equations. We also extend a theorem of Yoshizawa concerning the existence of periodic solutions of nonlinear differential systems to a general class of perturbed nonlinear systems of ordinary differential equations. (Received September 06, 2013)

1096-34-610 **J Diego Ramirez*** (diego.ramirez@lamar.edu), P.O. Box 10047, Beaumont, TX 77710.
An existence result for fractional differential equations of order $1 < \alpha < 2$ *with periodic boundary conditions.*

In this work we recall some results concerning the Coincidence Degree theory, also known as Mahwin's Coincidence Degree theory and define lower and upper solutions of fractional differential equations.

We apply these results to Caputo fractional differential equations of order α, $1 < \alpha < 2$, with periodic boundary conditions. We will show that if the problem has lower and upper solutions and satisfies certain conditions, then it has a periodic solution. (Received September 07, 2013)

1096-34-805 **Diandra M Ryan-Mas*** (dmr0602@wesminstercollege.edu), 1340 s 2200 East, Salt Lake City, UT 84108. *The Implementation of Novel Kernel Functions.* Preliminary report.

The use of support vector machines (SVMs) in binary classification has thus far been limited by the kernel functions upon which these machines rely. This research sought to numerically solve boundary value differential equations in order to implement novel kernel functions, allowing for a wider and more effective use of these SVMs. Techniques for generating and solving novel kernel functions, as well as their ability to classify data sets, will be discussed. (Received September 10, 2013)

1096-34-999 **Kowan T O'Keefe*** (kowanokeefe@gmail.com) and **Narayan Thapa** (narayan.thapa@minotstateu.edu), Minot, ND 58707. *Identification Problem in Pharmacokinetic-Pharmacodynamic Model for Treatment of Type II Diabetes Mellitus Using Metformin.*

Type II diabetes mellitus is a metabolic disorder in which a person has highly elevated blood glucose levels resulting from islet cells in the pancreas not producing enough insulin or from bodily tissues being resistant to the insulin that is produced. Metformin is a hypoglycemic drug that is widely used for treating Type II diabetes mellitus. Metformin works to reduce glucose levels in the blood by decreasing hepatic glucose output, increasing the rate of intestinal glucose consumption and increasing glucose uptake by muscle cells and fat tissue. In this work, an identification problem is investigated using an existing compartmental model for type II diabetes mellitus that is modified for this study. The effects of both oral and intravenous administration of metformin on this model are investigated. The parameters of the model are estimated by optimization using data from previously published works. (Received September 12, 2013)

1096-34-1031 **Tre Wells***, Morehouse College, Atlanta, GA 30314, and **Ronald E. Mickens**, Department of Physics, Clark Atlanta University, Atlanta, GA 30314. *Singularity Structure of the Leah-Sine Function, Lsn(t), at t = 0.*

The Leah-sine function [1] is the solution to the following initial-value problem

$$\frac{d^2x(t)}{dt^2} + x(t)^{\frac{1}{3}} = 0, \qquad x(0) = 0, \qquad \frac{dx(0)}{dt} = 1. \tag{*}$$

This solution does not have a Taylor series at $t = 0$ since all the derivatives, of order greater than the second, are not defined at t=0, i.e., they are unbounded. Using the method of dominant balance [2], we present arguments which show that $Lsn(t)$ has the following (asymptotic) structure

$$Lsn(t) \sim \left[t + d_1 t^{\frac{7}{3}} + d_2 t^{\frac{11}{3}}\right] f(t^4). \tag{**}$$

References

[1] J. Mann and R.E. Mickens, Abstracts of papers presented to the American Mathematical Society, vol.33 (#1, Issue 167, Winter 2012), Abstract 1077-35-2144, pp.171.

[2] C.M. Bender and S.A. Oeszag, Advanced Mathematical Methods for Scientists and Engineers (McGraw-Hill, New York, 1978); see pps. 83-88. (Received September 12, 2013)

1096-34-1197 **John R. Graef*** (john-graef@utc.edu), Department of Mathematics, The University of Tennessee at Chattanooga, Chattanooga, TN 37403, and **Lingju Kong** and **Qingkai Kong**. *Multiple Solutions of Systems of Fractional Boundary Value Problems: Part I.*

The authors discuss the existence of multiple solutions of systems of fractional boundary value problems of the form

$$\begin{cases} \frac{d}{dt}\left(\frac{1}{2}{}_0D_t^{-\beta}(u'(t)) + \frac{1}{2}{}_tD_T^{-\beta}(u'(t))\right) + \lambda\nabla F(t,u(t)) = 0, \ t \in [0,T], \\ u(0) = u(T) = 0, \end{cases}$$

where $T > 0$, $\lambda > 0$ is a parameter, $0 \leq \beta < 1$, $F : [0,T] \times \mathbb{R}^N \to \mathbb{R}$ is a given function, and ${}_0D_t^{-\beta}$ and ${}_tD_T^{-\beta}$ are the left and right hand Riemann-Liouville fractional integrals of order β, respectively. Using critical point theory, sufficient conditions are obtained for the existence of at least two nontrivial solutions of the system for λ large enough. (Received September 13, 2013)

1096-34-1198 **Lingju Kong**, **Qingkai Kong** and **Min Wang*** (min-wang@utc.edu), Department of Mathematics, University of Tennessee at Chattanooga, Chattanooga, TN 37403. *Existence and uniqueness of solutions for a fractional boundary value problem with a separated boundary condition.*

The authors study a nonlinear fractional boundary value problem with a separated boundary condition. The associated Green's function is constructed as a series of functions by applying the spectral theory. A criterion for the existence and uniqueness of solutions is obtained based on it. (Received September 13, 2013)

1096-34-1313 **John R. Graef** and **Lingju Kong*** (lingju-kong@utc.edu), Department of Mathematics, The University of Tennessee at Chattanooga, Chattanooga, TN 37403, and **Qingkai Kong**. *Multiple Solutions of Systems of Fractional Boundary Value Problems: Part II.*

Without the well-known Ambrosetti-Rabinowitz type growth conditions, the existence of infinitely many nontrivial solutions is established for the system of fractional boundary value problems of the form

$$\begin{cases} \frac{d}{dt}\left(\frac{1}{2}{}_0D_t^{-\beta}(u'(t)) + \frac{1}{2}{}_tD_T^{-\beta}(u'(t))\right) + \nabla F(t,u(t)) = 0, \ t \in [0,T], \\ u(0) = u(T) = 0, \end{cases}$$

where $T > 0$, $0 \leq \beta < 1$, ${}_0D_t^{-\beta}$ and ${}_tD_T^{-\beta}$ are, respectively, the left and right Riemann-Liouville fractional integrals of order β, $F : [0,T] \times \mathbb{R}^N \to \mathbb{R}$ is a given function. (Received September 14, 2013)

1096-34-1334 **Chuan Zhang*** (zhang@math.colostate.edu), Fort Collins, CO 80523, and **Gerhard Dangelmayr** and **Iuliana Oprea**. *Delay induced oscillations in neural networks.*

This presentation summarizes our main results on the storage and retrieval of cyclic patterns in Hopfield-type networks with delayed couplings, including delay induced bifurcations and oscillations in these networks.

First, we formulate and prove conditions for a cyclic pattern under which a network in accordance with the prescribed transitions can be constructed with the pseudoinverse learning rule. We call cyclic patterns satisfying such conditions admissible cycles and show that every admissible cycle is retrievable, i.e. the coupling leads to persistent oscillations in the network. Depending on their structural features, admissible cycles are classified into simple, separable and inseparable composite cycles, and each of these types of cycles gives rise to a specific network topology.

Second, we prove that cyclic patterns satisfying the same transition conditions can be stored and retrieved in the same network. In terms of their structural features, these cyclic patterns are respectively stored and retrieved as attracting limit cycles, unstable periodic solutions and long lasting transient oscillations. We also show that the transitions from fixed points to attracting limit cycles are multiple saddle-node bifurcations on limit cycles. (Received September 17, 2013)

1096-34-1392 **Bruce Reznick*** (reznick@math.uiuc.edu), Department of Mathematics, University of Illinois, 1409 W. Green St., Urbana, IL 61801. *Every math major should know this crazy theorem.*

THM: The solutions of the equation

$$((y'')^{-2/3})''' = 0$$

are precisely the non-degenerate conic sections.

We shall give two old, elementary and comprehensible proofs.

This theorem appears in Sylvester (1886), although Cartan (1937) attributes it to Halphen (1870's). The essentially equivalent version

$$y''(40(y''')^3 - 45y''y'''y'''' + 9(y'')^2y''''') = 0,$$

which is valid for non-vertical lines as well, goes back to Monge (1809). More sophisticated interpretations of this result have been given by Lascoux (2006). (Received September 15, 2013)

1096-34-1660 **Sowmya Muniswamy*** (sxm6009@louisiana.edu), Department of Mathematics, University of Louisiana at Lafayette, Lafayette, LA 70504-1010, and **Aghalaya S. Vatsala**. *Superlinear Convergence via Iterative Methods for Scalar Caputo fractional differential equations with applications.* Preliminary report.

In this work we have developed superlinear convergence method to compute coupled lower and upper solutions to any desired interval for scalar Caputo fractional differential equations of order q, where $0 < q < 1$. This has been achieved via generalized quasilinearization method and generalized monotone method. Further, using the coupled lower and upper solutions computed above, we develop monotone sequences which converge to a unique solution. The rate of convergence of these sequences is superlinear. We provide some numerical results as an application of our theoretical results. (Received September 16, 2013)

1096-34-2169 **Omar Abed Elkareem Abu Arqub*** (o.abuarqub@bau.edu.jo), Department of Mathematics, Al-Balqa Applied University, Salt 19117, Jordan, amman, 00962, Jordan. *An iterative method for solving boundary value problems of fourth-order and second-order differential equation systems.* Preliminary report.

In this paper, reproducing kernel Hilbert space method is introduced as an efficient solver for boundary value problems of fourth-order and second-order differential equation systems where two reproducing kernel functions are used throughout the evolution of the algorithm to obtain the required nodal values of the unknown variables. The solution methodology is based on generating the orthogonal basis from the obtained kernel function in the space $W_2^5[a,b]$. After that, the orthonormal basis is constructing in order to formulate and utilize the solutions in the same space. In addition to that, an error estimation and bound based on the use of reproducing kernel theory has been carried out. Two numerical test problems including linear and nonlinear systems were analyzed to illustrate the procedure and confirm the performance of the proposed method. The numerical results show that the proposed algorithm is a robust and accurate procedure for solving such types of systems. (Received September 17, 2013)

1096-34-2173 **M. Sambandham*** (msambandham@yahoo.com), Department of Mathematis, 830 Westview Drive, Morehouse College, Atlanta, GA 30314, and **G. S. Ladde**. *Stability Analysis of Stochastic Large-Scale Approximation Scheme.* Preliminary report.

Variational comparison theorems for a class of stochastic hybrid systems are developed. These comparison results are applied to study the relative stability analysis of stochastic large-scale approximation schemes for an initial value problem in the framework of the stochastic hybrid system. Suitable examples are given to illustrate the results. (Received September 17, 2013)

1096-34-2338 **Wendy K. Caldwell*** (wcaldwe6@utk.edu), **Benjamin Freedman**, **Luke Settles**, **Michael M. Thomas**, **Anarina Murillo**, **Erika Camacho** and **Stephen Wirkus**. *Substance Abuse via Legally Prescribed Drugs: The Case of Vicodin in the United States.*

Vicodin is the most commonly prescribed pain reliever in the United States. Research indicates that there are two million people currently abusing Vicodin, the majority of which were initially exposed via prescription. Our goal is to determine the most effective strategies for reducing the population of Vicodin abusers. We focus on whether prevention methods aimed at educating on the potential for drug abuse or treatment methods implemented after abuse will have a greater impact. We consider one linear and two non-linear compartmental models in which medical users of Vicodin can transition into the abuser compartment or leave the population by no longer taking the drug. Abusers can transition into a treatment compartment, leaving the population through successful treatment or relapsing and re-entering the abusive compartment. The linear model assumes no social interaction, while both non-linear models do. Sensitivity analyses are conducted varying the rates of success of these intervention methods to determine which strategy has the greatest impact on controlling the population of Vicodin abusers. From these models, we determine that manipulating parameters tied to prevention measures has a greater impact on reducing the population of abusers than those associated with treatment. (Received September 17, 2013)

1096-34-2341 **Mohammed Hamdi Al-smadi*** (mhm.smadi@yahoo.com), PO. Box 210, Jerash 26110, Jordan, Jerash, Outside US 00962, Jordan. *Analytical solutions of fuzzy initial value problems by RKHS method.* Preliminary report.

In this article, numerical solution of fuzzy initial value problems under strongly generalized differentiability by means of the reproducing kernel Hilbert space method is considered. The new approach provides the solution in the form of a rapidly convergent series with easily computable components using symbolic computation software in the space W_2^2 [a,b]. The proposed technique is applied to a two test examples to illustrate the accuracy, efficiency, and applicability of the method. The results reveal that the method is very effective, straightforward and simple. (Received September 17, 2013)

1096-34-2491 **Qing Wang*** (qwang@shepherd.edu), P.O. Box 935, Shepherdstown, WV 25443, and **David J. Klinke** (david.klinke@mail.wvu.edu) and **Zhijun Wang** (zwang@shepherd.edu). *Modeling and Qualitative Analysis of Immune Response to Tumor Growth.*

In this study, we developed a multi-scale non-spatial ODE model to describe a T cell mediated immune response to tumor growth. Model parameters were calibrated to some existing experimental data by a Markov Chain Monte Carlo (MCMC) algorithm. By quantifying the adenovirus-elicited T cell response and interactions between T cells, cytokines, and tumor cells, the validated model captured the modest suppression of tumor cell growth in a transplantable mouse model for metastatic melanoma. Stability analysis and its biological relevance were also discussed. The model provides a platform for in silico screening of optimal cancer treatment. This research has been supported by the NIGMS of the NIH grant as part of the WV-INBRE (P20GM103434). (Received September 17, 2013)

1096-34-2589 **Anton Dzhamay*** (adzham@unco.edu), School of Mathematical Sciences, University of Northern Colorado, Greeley, CO 80526. *On the geometry of difference Painlevé equations with symmetry group $E_6^{(1)}$.* Preliminary report.

It is known that, for each geometric type of a discrete Painlevé equation in Sakai's classification, there are many non-equivalent equations that correspond to different translation direction in the Picard lattice. It is also known that there are different sources for discrete Painlevé equations, such as the singularity confinement principle, isomonodromic approach, reductions from lattice equations, and so on. In this project we study the relationship between these different examples of difference Painlevé equations of type $A_2^{(1)*}$ (with the symmetry group $E_6^{(1)}$) by explicitly identifying their Okamoto surfaces of initial conditions and then comparing the resulting translational directions in the Picard lattice. (Received September 17, 2013)

35 ► *Partial differential equations*

1096-35-71 **Alejandro Vélez-Santiago*** (alejandro.velez2@upr.edu). *On the well-posedness of first order variable exponent Cauchy problems with Wentzell-Robin boundary conditions on arbitrary domains.*

We define the notion of relative capacity of variable exponent type, referred in this article as the relative $p(\cdot)$-capacity, and use this approach to obtain a necessary and sufficient condition for the well-posedness of the corresponding parabolic boundary value problems involving the $p(\cdot)$-Laplace operator and Wentzell-Robin boundary conditions on arbitrary domains. Consequently, we were able to obtain the realization of the $p(\cdot)$-Laplacian with Wentzell-Robin boundary conditions on a large class of domains that may include many non-smooth and fractal domains, and under very weak assumptions on the exponent $p(\cdot)$ and measures on the boundary. (Received July 09, 2013)

1096-35-72 **Weilin Li*** (wl298@cornell.edu) and **Robert S Strichartz** (str@math.cornell.edu). *Boundary Value Problems on a Half Sierpinski Gasket.*

We study boundary value problems for the Laplacian on a domain Ω consisting of the left half of the Sierpinski Gasket (SG), whose boundary is essentially a countable set of points X. For harmonic functions we give an explicit Poisson integral formula to recover the function from its boundary values, and characterize those that correspond to functions of finite energy. We give an explicit Dirichlet to Neumann map and show that it is invertible. We give an explicit description of the Dirichlet to Neumann spectra of the Laplacian with an exact count of the dimensions of eigenspaces. We compute the exact trace spaces on X of the L^2 and L^∞ domains of the Laplacian on SG. In terms of the these trace spaces, we characterize the functions in the L^2 and L^∞ domains of the Laplacian on Ω that extend to the corresponding domains on SG, and give an explicit linear extension operator in terms of piecewise biharmonic functions. (Received July 09, 2013)

1096-35-83 **Kazuo Yamazaki*** (kyamazaki@math.okstate.edu), 401 Mathematical Sciences Building, Department of Mathematics, Oklahoma State University, Stillwater, OK 74078. *Global regularity issue of fluid dynamics partial differential equations.*

We discuss recent developments on the global regularity issue of fluid dynamics partial differential equations, which remains a very challenging topic in mathematical analysis. Our discussion includes the Navier-Stokes and magnetohydrodynamics systems as well as active scalars such as surface quasi-geostrophic and incompressible porous media equations. We consider the global regularity issue with dissipative (and diffusive) terms with fractional Laplacians with different range of power and elaborate on the Serrin-type regularity criteria and global regularity in the logarithmically super-critical case. (Received September 17, 2013)

1096-35-89 **Murat Akman*** (murat.akman@uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506, and **John Lewis** and **Andrew Vogel**. *Hausdorff dimension of a certain measure.* Preliminary report.

In the first part of my talk I will discuss the Hausdorff dimension of a measure related to a positive weak solution of a certain partial differential equation in a simply connected domain. Our work generalizes work of Lewis and coauthors when the measure is $p-$harmonic and also for $p=2$, the well known theorem of Makarov regarding the Hausdorff dimension of harmonic measure relative to a point in a simply connected domain. In the second part of my talk I will present a recent result in the study of Hausdorff dimension of p-harmonic measure for $p \geq n$ when p-harmonic function is defined on an open subset of $\mathbb{R}^n$ and vanishing on a portion of boundary of this open set. (Received July 19, 2013)

1096-35-90 **Cynthia V. Flores***, cynthia@math.ucsb.edu. *On decay properties of solutions to the IVP for the Benjamin-Ono equation.*

In this work we investigate unique continuation properties of solutions to the initial value problem associated to the Benjamin-Ono equation given by

$$\begin{cases} \partial_t u + \mathcal{H}\partial_x^2 u + u\partial_x u = 0, \quad x,t \in \mathbb{R} \\ u(x,0) = u_0(x) \end{cases} \tag{1}$$

with $\mathcal{H}$ denoting the Hilbert transform

$$\begin{aligned} \mathcal{H}f(x) &= \frac{1}{\pi}\,\text{p.v.}\left(\frac{1}{x} * f\right)(x) = \frac{1}{\pi}\lim_{\epsilon\downarrow 0}\int_{\epsilon<|y|<\frac{1}{\epsilon}} \frac{f(x-y)}{y}dy \\ &= -i\,(\text{sgn}(\xi)\,\widehat{f}(\xi))^{\check{}}(x). \end{aligned}$$

in weighted Sobolev spaces $Z_{s,r} = H^s(\mathbb{R}) \cap L^2(|x|^{2r}dx)$ for $s \in \mathbb{R}$, and $s \geq 1$, $s \geq r$. More precisely, we prove that the uniqueness property based on a decay requirement at three times can not be lowered to two times even by imposing stronger decay on the initial data. (Received July 19, 2013)

1096-35-119 **Tepper L Gill*** (tgill@access4less.net), Department of E&CE and Mathematics, 2300 6th St. NW, Washington, DC 20059. *Foundations for the Thompson problem.* Preliminary report.

n 1972, P. D. Thompson used the amplitudes of a set of orthogonal eiginvalues on the two sphere as the coordinates in an infinite-dimensional phase space to model the climate over a region of earth. This allowed him to derive the probability distribution for an ensemble of randomly forced two-dimensional viscous flows as the solution of the continuity equation for the phase flow. He obtained a partial differential equation in infinitely many variables for the probability density. He was criticized, because mathematically the equation had no meaning at the time. The purpose of this talk is to discuss progress on this problem. (Received July 31, 2013)

1096-35-139 **Eric Sullivan*** (esullivan@carroll.edu), Carroll College, Helena, MT. *A nonlinear PDE model for evaporation in unsaturated soils.*

In unsaturated soils it is well known that the diffusion of water vapor is inaccurately predicted by classical Fickian-based models. Much effort has been made over the past decades to describe this phenomenon, known as *enhanced vapor diffusion*, but to date a complete theoretical foundation is absent. The goal of this presentation is to show how Hybrid Mixture Theory is used to derive a vapor diffusion equation that couples both the Darcy advection and Fickian diffusion of water vapor in unsaturated soils with the chemical potential. Contrary to historically used models, the nonlinear PDE presented gives a new form of the vapor diffusion coefficient that does not rely on an empirical fitting parameter. However, upon comparing with experimental values the new diffusion coefficient gives good agreement while only taking into account a-priori information about the experimental setup. (Received August 07, 2013)

1096-35-151 **Arni S.R. Srinivasa Rao***, Georgia Regents University, Augusta, GA 30912. *PDE Models in Measuring Global Sustainability.*

Abstract. Understanding sustainability through modeling involves one of the complex and interdisciplinary activities where mathematics play a key role. For measuring the status of the sustainability, we need global models with all-round global data, for example, from atmosphere, oceans, vegetation, food, wetlands, species and several environmental parameters. However such a global model could have components of sub-models (or local models) quantifying sustainability status at various geographic regions on our planet. PDE models and sustainability indices are proposed which can be used with real-world data. These proposed PDE models and measures of sustainability involve appropriate weight functions to capture relevance of six major factors of overall sustainability on the panet. A method to obtain weights of Riemann Stieltjes integrals is described. A numerical example will be presented during the talk. These computationally intense models should be able to update global and local sustainability status periodically such that time-dependent action oriented policies can be skimmed from these efforts. Key words and phrases: Key words: Modeling, Partial Differential Equations, Riemann Weight Functions.2000 Mathematics Subject Classification: MSC: 92D40, 35Q80,26A42 (Received August 09, 2013)

1096-35-154 **Ko-Shin Chen*** (koshchen@indiana.edu), Dept. of Math., Indiana U., 831 E. Third St., Bloomington, IN 47405, and **Peter Sternberg** (sternber@indiana.edu), Dept. of Math., Indiana U., 831 E. Third St., Bloomington, IN 47405. *Dynamics of Ginzburg-Landau and Gross-Pitaevskii Vortices on Manifolds.*

In this talk we consider the dissipative heat flow and conservative Gross-Pitaevskii dynamics associated with the Ginzburg-Landau energy posed on a 2-manifold. We will show that in the $\varepsilon \to 0$, the vortices of the solution to these two problems evolve according to the gradient flow and Hamiltonian point-vortex flow respectively, associated with the renormalized energy. For the heat flow on a sphere, we will also present an annihilation result for the limiting system of ODE's and will derive some weighted energy identities. (Received August 10, 2013)

1096-35-155 **Ko-Shin Chen*** (koshchen@indiana.edu), Dept. of Math, Indiana U., 831 E. Third St., Bloomington, IN 47405. *Ginzburg-Landau Vortices on Manifolds.*

We investigate Ginzburg-Landau energy posed on 2-manifold. We will show that a critical point is unstable if it has a vortex at a location where Gauss curvature is positive. Furthermore, for a surface of revolution, any critical point having vortices is unstable regardless of Gauss curvature at vortex locations. Next, we will discuss the Ginzburg-Landau heat flow on a surface of revolution with boundary. By an extra geometric assumption, we will show that all vortices of the solution disappear after a finite time. (Received August 10, 2013)

1096-35-207 **Jean Dolbeault**, **Maria J. Esteban** and **Michael Loss*** (loss@math.gatech.edu), School of Mathematics, Georgia Tech, 686 Cherry Street, Atlanta, GA 30332-0160. *Nonlinear flows and rigidity results on compact manifolds.*

This talk is about a certain class of non-linear PDEs on a compact connected Riemannian manifolds without boundary. The problem is to prove that there are no solutions other than the constant function. These rigidity results yield sharp Sobolev type inequalities. While some of the results date back to the 90-ies, a new perspective has emerged in the last five years. The idea is to use porous media or fast diffusion flows that yield relatively straightforward proofs for such rigidity results. (Received August 19, 2013)

1096-35-208 **Xiangwen Zhang*** (xzhang@math.columbia.edu), Department of Mathematics, Columbia University, MC 4421, 2990 Broadway, New York, NY 10027. *A proof of the Alexanderov's uniqueness theorem for convex surfaces in $\mathbb{R}^3$.*

A classical uniqueness theorem of Alexandrov says that: if M and M' are two closed strictly convex C^2 surface in $\mathbb{R}^3$ and satisfy $f(\kappa_1, \kappa_2) = f(\kappa_1', \kappa_2')$, at points of M, M' with parallel normals, for some C^1 function $f(y_1, y_2)$ with $\frac{\partial f}{\partial y_1}\frac{\partial f}{\partial y_2} > 0$, then M is equal to M' up to a translation. We will talk about a new PDE proof for this thorem by using the maximal principle. More generally, we prove a version of this theorem with the minimal regularity assumption: the spherical hessians of the supporting functions for the corresponding convex bodies as Radon measures are nonsingular. This is a joint work with P. Guan and Z. Wang. (Received August 19, 2013)

1096-35-234 **John Albert** (jalbert@ou.edu), 601 ELM Ave, Norman, OK 73019, and **Santosh Bhattarai*** (bhattarais@trocaire.edu), 360 Choate Ave, Buffalo, NY. *Symmetric rearrangement and the stability of NLS-KdV solitary waves.*

We prove existence and stability results for a two-parameter family of solitary-wave solutions to a system in which an equation of nonlinear Schrodinger type is coupled to an equation of Korteweg-de Vries type. Such systems model interactions between short and long dispersive waves. The results extend, in a significant way, earlier results of J. Angulo (2006), J. Albert and J. Angulo (2003), and L. Chen (1999). Our proof involves the characterization of solitary-wave solutions as minimizers of an energy functional subject to two constraints. To establish the precompactness of minimizing sequences via concentrated compactness, we develop new method of proving the sub-additivity of the problem with respect to both constraint variables jointly. (Received August 21, 2013)

1096-35-267 **David Ambrose*** (ambrose@math.drexel.edu), 3141 Chestnut St., Philadelphia, PA 19104, and **Jerry Bona** and **David Nicholls**. *Ill-Posedness Issues for Truncated Series Models of Water Waves.*

Some numerical methods for water waves, such as the Craig-Sulem method, involve expanding terms in the water wave evolution equations as series, truncating those series, and then simulating the resulting equations. For one such scheme, we present analytical evidence that the truncated system is in fact ill-posed; this involves further reducing the evolution equations to a model for which we can prove ill-posedness. We then present numerical evidence that the full truncated system is ill-posed, showing that arbitrarily small data can lead to arbitrarily fast blowup. We present this numerical evidence for multiple levels of truncation. We are able to prove that by adding a viscosity to the system, we instead arrive at a well-posed initial value problem. (Received August 25, 2013)

1096-35-273 **Junfang Li**, Department of Mathematics, University of Alabama at Birmingham, Birmingham, AL 35294, and **Xiangjin Xu*** (xxu@math.binghamton.edu), Department of Mathematical Sciences, Binghamton University-SUNY, 4400 Vestal Parkway East, Binghamton, NY 13902. *Li-Yau type gradient estimates and new bound estimates for the parabolic kernel of the Schrödinger operator on manifolds with negative curvature.* Preliminary report.

In the first part of this talk, we get new Li-Yau type gradient estimates for positive solutions of parabolic euations of the type

$$(\Delta_g - q(x,t) - \partial_t)u(x,t) = 0$$

on Riemmannian manifolds with $Ricci(M) \geq -k$, $k \in \mathbb{R}$. As applications, several parabolic Harnack inequalities are obtained and they lead to new estimates on the parabolic kernel of the Schrödinger operator on manifolds with negative curvature, which generalized the classical results by Li and Yau [Acta Math. 156 (1986) 153-201.] (Received August 26, 2013)

1096-35-275 **Zachary Bradshaw*** (zb8br@virginia.edu). *On the radius of analyticity of solutions to the 3D Navier-Stokes equations at interior points of a bounded domain.*

Sharp lower bounds are given for the radius of analyticity of the complex extensions of the 3D Navier-Stokes equations defined on a domain possessing a boundary. Specifically, for a fixed interior point, the analyticity radius is increasing (locally) in time in a fashion depending on the distance from the point to the boundary, as well as the initial data and the boundary pressure data. A geometric measure-type regularity criteria for bounded domains is included as an application of our work. (Received August 26, 2013)

1096-35-278 **Ira Herbst*** (iwh@virginia.edu), Kerchof Hall, University of Virginia, 141 Cabell Drive, Charlottesville, VA 22904, and **Erik Skibsted**. *Exponential Decay of Eigenfunctions of Higher Order Elliptic PDE's.*

We study exponential decay of eigenfunctions of self-adjoint elliptic operators on $\mathbb{R}^d$. We show that the possible decay rates can be determined by solving certain algebraic equations. In addition we show absence of super-exponentially decaying eigenfunctions. (Received August 26, 2013)

1096-35-289 **Pei Pei*** (s-ppei1@math.unl.edu), University of Nebraska–Lincoln, Department of Mathematics, 203 Avery Hall, Lincoln, NE 68588. *Well-posedness and decay of energy for Mindlin-Timoshenko plate equations.*

This is a study of semilinear Reissner-Mindlin-Timoshenko (RMT) plate equations. This PDE system represents an extension of the Timoshenko beam model to plates and accounts for shear deformations. The primary feature of the considered model is the interplay between nonlinear viscous interior damping and nonlinear source terms. We begin by verifying local and global existence and uniqueness of solutions as well as their continuous dependence on the initial data in appropriate function spaces. Moreover, a blow-up result is proved for solutions with negative initial energy. Next, by developing the potential well theory for the RMT system, we first prove global existence for potential well solutions without restricting the source exponents, and then derive explicit energy decay rates dependent on the order of the damping exponents, in the end, we verify a blow-up result for positive “total” initial energy. (Received August 26, 2013)

1096-35-314 **Xianpeng Hu***, Apt 9U, 2 Washington Square Village, New York, NY 10012. *On solvability of elastodynamic flows.* Preliminary report.

This talk aims at the solvability of elastodynamic flows. The flow takes the form of Euler equations. The global solvability of elastodynamic flows is verified under the conditions that the initial data is small and the null structure is satisfied. (Received August 27, 2013)

1096-35-334 **Yue Chen*** (chenyue0715@uky.edu), University of Kentucky, 767 Patterson Office Tower, Lexington, KY 40506, and **Robert Lipton**. *Double Negative Behavior in Metamaterials.*

A generic class of metamaterials is introduced and is shown to exhibit frequency dependent double negative effective properties. In this talk, we introduce a rigorous method for calculating the frequency intervals where either double negative or double positive effective properties appear and show how these intervals imply the existence of propagating Bloch waves inside sub-wavelength structures. (Received August 28, 2013)

1096-35-339 **Fabio Pusateri***, fabiop@math.princeton.edu. *Global existence for water waves in two dimensions.*

We consider the water waves system for the evolution of a perfect fluid with a free surface, in 2 spatial dimensions, under the influence of gravity. For sufficiently smooth and localized initial data we prove global existence of small solutions. We also prove that the asymptotic behavior of solutions as time goes to infinity is different from linear, unlike the 3d case. Joint work with A. Ionescu. (Received August 29, 2013)

1096-35-367 **Soyeun Jung*** (soyjung@indiana.edu), 831 E 3rd St., Bloomington, IN 47405. *Pointwise asymptotic behavior of modulated periodic reaction-diffusion waves.*

We discuss, under standard spectral stability assumptions, pointwise stability and asymptotic behavior of localized modulated spatially periodic traveling waves $u(x,t)=\bar{u}(x-at)$ of systems of reaction-diffusion equations of form $u_t=u_{xx}+f(u)$, where $(x,t)\in\mathbb{R}\times\mathbb{R}^+$, $u\in\mathbb{R}^n$, and $f:\mathbb{R}^n\to\mathbb{R}^n$ is sufficiently smooth. By working with the periodic resolvent kernel and the Bloch-decomposition, we first establish pointwise bounds for the Green function of the linearized equation associated with $\bar{u}$. With our linearized estimates together with a nonlinear iteration scheme developed by Johnson-Zumbrun, we obtain pointwise asymptotic behavior of periodic traveling waves $\bar{u}(x)$ by showing that perturbations of $\bar{u}(x)$ converge to the heat kernel under small initial perturbations, $|u_0|\le E_0e^{-|x|^2/M}$ with $|u_0|_{H^2}\le E_0$, and $|u_0|\le E_0(1+|x|)^{-r}$, $r>2$ with $|u_0|_{H^2}\le E_0$ respectively, where $E_0>0$ sufficiently small and $M>0$ sufficiently large. Here, we emphasize again that it is the pointwise description that is the main new aspect of our research. (Received August 30, 2013)

1096-35-408 **Thomas G Anderson*** (tga3@njit.edu), 156 Warren St, Apt 616, Newark, NJ 07103, and **George Avalos**, **Elizabeth Galvin**, **Ian Kessler**, **Michelle Kleckner**, **Daniel Toundykov** and **William Tritch**. *Long-term Behavior of Solutions to a Wave Equation with Degenerate Damping.*

The model of interest is a semilinear wave equation with degenerate damping

$$u_{tt}-\partial_x(p(x)u_x)+|u|^r u_t=0, x\in(0,1), t>0$$

where $p(x)\ge c>0$ is continuous, $r>0$, and the sought after function u satisfies homogeneous Dirichlet conditions. The well-posedness of this problem has been studied; however, little is known to date about the energy dissipation rates of its solutions. The primary challenge is that it is not clear how to estimate the kinetic energy of a state in terms of the dissipation feedback that deteriorates at small amplitudes. We present an alternate proof of existence and uniqueness using a contraction mapping argument. In addition, we establish local existence of regular ($H^{1+k}\times H^k$) solutions. Then, a numerical simulation of this model will be presented employing a combination of a finite-element scheme and the fixed point method. Some results concerning the asymptotic energy decay rates and their uniformity will be discussed. Examples of these energy decay rates will also be presented. This work was done as a part of an REU project at the University of Nebraska-Lincoln. (Received September 02, 2013)

1096-35-412 **Maleafisha Stephen Tladi*** (stephen.tladi@ul.ac.za), Department of Mathematics & Applied Mathemati, University of Limpopo, Sovenga, Limpopo 0727, South Africa. *Existence And Stability In Ageostrophic Flows With Viscoelastic-type Reynolds Stress.*

The author studies ageostrophic equations describing the motion of a viscous incompressible stratified fluid in a rotating system which is relevant, e.g., for Lagrangian coherent structures. These equations consist of the

Navier-Stokes equations with bouyancy-term and Coriolis-term in beta-plane approximation, the divergence-constraint, and a diffusion-type equation for the density variation. They are considered in a plane layer with periodic boundary conditions in the horizontal directions and stress-free conditions at the bottom and the top of the layer. Additionally, the author considers this model with Reynolds stress, which adds hyper-diffusivity terms of order 6 to the equations. This manuscript focuses primarily on deriving ageostrophic model equations for geophysical fluids, showing existence and uniqueness of solutions, and outlining how Lyapunov functions can be used to assess stability. The main emphasis of the paper is on Faedo-Galerkin approximations as well as LaSalle invariance principle for asymptotic stability and attraction. (Received September 03, 2013)

1096-35-451 **A Abebe*** (anabebe@uncg.edu), **M Chhetri**, **L Sankar** and **R Shivaji**. *Existence and nonexistence of positive solutions to exterior domain superlinear semipositone system.*

In this article, under certain conditions on the parameter λ, we prove existence and nonexistence of positive solutions to superlinear semipositone eigenvalue problem of the form

$$\begin{array}{rcll} -\Delta u(x) & = & \lambda K_1(|x|)f(v(x)), & x\in\Omega \\ -\Delta v(x) & = & \lambda K_2(|x|)g(u(x)), & x\in\Omega \\ u=v & = & 0, & |x|=r_0 \\ u\to 0 & , & v\to 0, & |x|\to\infty \end{array} \tag{1}$$

where $\lambda > 0$ is a parameter, $\Delta u := \div(\nabla u)$ is the Laplace operator and Ω is a $\mathbb{R}^N$ minus the unit ball, $N \geq 2$. That is $\Omega = \left\{x \in \mathbb{R}^N \mid |x| > r_0 \ , N > 2\right\}$. Suppose the nonlinearities $f : [0,\infty) \to \mathbb{R}$ and $g : [0,\infty) \to \mathbb{R}$ are C^1 and nondecreasing functions. (Received September 03, 2013)

1096-35-474 **Mimi Dai*** (mdai@uic.edu). *Stability of Solutions to the Dissipative Quasi-Geostrophic Equation.*

We consider the steady-state Surface Quasi-Geostrophic equation in the whole space $\mathbb{R}^2$ driven by a forcing function f. The class of source functions f under certain assumptions yield the existence of at least one solution with finite energy (finite L^2 norm). These solutions are unique among all solutions with finite energy. The constructed solutions are also shown to be stable in the following sense: If Θ is such a solution then any viscous, incompressible flow in the whole space, driven by f and starting with finite energy, will return to Θ. (Received September 04, 2013)

1096-35-478 **B. S. Tilley*** (tilley@wpi.edu), Dept. Mathematical Sciences, Worcester Polytechnic Institute, 100 Institute Road, Worcester, MA 01609, and **S. Jimenez** (silvia.jimenez.bolanos@gmail.com) and **B. Vernescu** (vernescu@wpi.edu). *Soret effects in electrokinetically-driven heat exchangers for electronics applications.*

We are interested in extending classical asymptotic approaches to allow for the spatial pattern wavenumber to vary on the macroscale variables and to find how changes in microstructure geometry affect macroscopic properties and transport. To this end, we consider here the thermal transport of a weakly dielectric coolant through nonuniformly spaced laminates, under an applied electric field, as a simple model for heat sinks in electronics. Power is continuously being generated by the laminates, and the local rates of heat and ion transport depend on the local electric potential, local ion concentrations, and local thermal gradients in the coolant. We find a coupled system of partial differential equations that describe the local microscale temperature and deviations from the Darcy pressure. Microscale values of all of these quantities are known in terms of the solutions to these effective equations. Charge aggregation effects are seen in the isothermal case, and the effect of ionic species transport due to the local temperature field impacts the overall heat transport capabilities of the heat exchanger. We are especially interested in geometries in the laminate spacing which allow for better thermal transport by the coolant for a prescribed power distribution. (Received September 04, 2013)

1096-35-486 **Philip T. Gressman** (gressman@math.upenn.edu), David Rittenhouse Laboratory, 209 South 33rd Street, Philadelphia, PA 19104, **Vedran Sohinger*** (vedranso@math.upenn.edu), David Rittenhouse Laboratory, 209 South 33rd Street, Philadelphia, PA 19104, and **Gigliola Staffilani** (gigliola@math.mit.edu), Massachusetts Institute of Technology, 77 Massachusetts Avenue, Building E17, Cambridge, MA 02139. *The Gross-Pitaevskii hierarchy on the three-dimensional torus.*

In this talk, we will study the Gross-Pitaevskii hierarchy on the spatial domain $\mathbb{T}^3$. In the first part of the talk, we will prove a conditional uniqueness result for the hierarchy. As a result of our analysis, we will obtain a sharp range of integrability exponents in the key spacetime estimate. In the second part of the talk, we will add randomness into the problem by randomizing the collision operators on the Fourier domain. In this randomized setting, we will study the limiting behavior of Duhamel iteration terms. The first part is based on joint work with Philip Gressman and Gigliola Staffilani. The second part is based on joint work with Gigliola Staffilani. (Received September 04, 2013)

1096-35-491 **Mihaela Ignatova*** (mihaelai@stanford.edu), **Igor Kukavica** and **Lenya Ryzhik**. *The Harnack inequality for second-order elliptic and parabolic equations with divergence-free drifts of low regularity.*

We first establish the Harnack inequality and the one-sided Liouville theorem for second-order elliptic equations with divergence-free drifts with regularity lower than the scale-invariant spaces. Then, we address the more challenging parabolic case by adapting the classical Moser iteration technique to parabolic equations with divergence free drifts of low regularity. (Received September 04, 2013)

1096-35-492 **Mayukh Mukherjee*** (mayukh@live.unc.edu). *Travelling wave solutions for nonlinear Schrödinger and nonlinear Klein-Gordon equations on Riemannian manifolds.*

In this talk, we focus on travelling wave solutions to NLS and NLKG (the emphasis is on NLKG) equations on Riemannian manifolds, mainly compact ones. These are solutions of the form

$$v(t,x) = e^{i\lambda t}u(g(t)x)$$

with $\lambda \in \mathbb{R}$, where $g(t)$ is a one-parameter family of isometries flowing by the Killing field X. We outline methods of establishing existence of travelling wave solutions via energy minimisation methods and proving that solutions are nontrivial (not standing) on a sufficiently large class of isotropic compact manifolds for at least a non-empty set of parameters (the same parameters that show up in the NLS and NLKG equations). We will mention certain sharp estimates on low dimensional spheres and outline the subelliptic analysis on S^n for the NLKG when X has length ≤ 1. Here we will observe some phenomena which have no parallel in the flat Euclidean space; a certain degree of curvature of the space is essential. We will finish by stating a few related results on complete noncompact manifolds which have a certain radial symmetry. (Received September 04, 2013)

1096-35-504 **Justin Ziegler*** (justin.ziegler.2@my.minotstateu.edu) and **Narayan Thapa** (narayan.thapa@minotstateu.edu), Minot, ND 58703. *Finite Difference Method for the Black-Scholes Option Pricing Model.*

Finance is one of the most rapidly changing and fastest growing areas in the corporate business world. Through these changes, modern financial instruments have become extremely complex. As a result, mathematical models are essential to implement and price these intricate financial instruments. In this particular interdisciplinary approach, we focus on a groundbreaking result in finance via mathematics called the Black-Scholes option pricing model. In this work, we implement finite difference methods to solve the Black-Scholes equation. Stability, error, and numerical examples are also explored. (Received September 12, 2013)

1096-35-506 **Chloe L Ondracek*** (chloe.ondracek@my.minotstateu.edu), Minot, ND 58703, and **Narayan Thapa** (narayan.thapa@minotstateu.edu), Minot, ND 58707. *Identification Problem in Parabolic Partial Differential Equation.*

In this work, we consider an inverse problem involving the identification and estimation of distributed parameters in parabolic type initial boundary value problem. Unique solution of the initial boundary value problem is derived. The time dependent parameter is determined by using observational data. (Received September 12, 2013)

1096-35-524 **Zaher Hani*** (hani@cims.nyu.edu), 251 Mercer Street, New York, NY 10012. *Out-of-equilibrium dynamics for the nonlinear Schrodinger equation.* Preliminary report.

I will discuss some recent progress on results related to the out-of-equilibrium dynamics of nonlinear Schrodinger equations on compact and partially compact domains (like cylinders and wave-guide manifolds). I will focus on the phenomenon of energy cascade in which the energy moves its concentration zones from low to high frequencies (direct cascade). Part of this is joint work with B. Pausader, N. Tzvetkov, and N. Visciglia. (Received September 05, 2013)

1096-35-541 **Vasilis Chousionis**, **Valentino Magnani** and **Jeremy T Tyson*** (tyson@math.uiuc.edu). *Removable sets for homogeneous linear PDE in Carnot groups.*

We will discuss the problem of removable sets for solutions of homogeneous linear PDE in nilpotent stratified Lie groups (also known as Carnot groups). We quantify the role of the regularity of solutions and the degree of the equation in connection with the size (measured in terms of Hausdorff dimension) of allowed removable sets. In the Euclidean case such results are classical, considered by various authors including Carleson, David, Mattila, Harvey and Polking.

The connection between this topic and fractal geometry is three-fold. First, the internal metric geometry of each non-abelian Carnot group is partially fractal (in the "inaccessible" or non-horizontal directions). Second, the proofs of several of the removability results use dyadic-type tilings of such spaces; in non-abelian Carnot groups such tilings always have a fractal structure. The first construction of fractal tilings of nilpotent stratified Lie groups is due to Strichartz. Finally, we will present examples demonstrating the sharpness of such removability theorems; these examples consist of various self-similar Cantor-type constructions. (Received September 05, 2013)

1096-35-560 **Hantaek Bae*** (hantaek@math.ucdavis.edu) and **Marco Cannone** (marco.cannone@univ-mlv.fr). *Gevrey regularity of the Navier-Stokes Equations and its applications.*

In this talk, we present how to obtain global (in time) Gevrey regular solutions to the Navier-Stokes equations with small data in critical spaces. This has several applications in the study of long time dynamics. We here show Log-Lipschitz regularity of mild solutions. (Received September 06, 2013)

1096-35-582 **Alexander Pankov*** (alexander.pankov@morgan.edu). *Homogenization of nonlinear elliptic operators and periodic approximations.*

We show that, under sufficiently general assumptions, nonlinear homogenization problems can be approximated by periodic homogenization problems. In particular, this is so for random and almost periodic problems. In addition, we discuss few open problems. (Received September 06, 2013)

1096-35-638 **Walter Craig*** (craig@math.mcmaster.ca), Fields Institute, 222 College Street, Toronto, Ontario M5T 3J1, Canada. *On the size of the Navier - Stokes singular set.*

Consider the hypothetical situation in which a weak solution $u(t, x)$ of the Navier-Stokes equations in three dimensions develops a singularity at some singular time $t = T$. It could do this by a failure of regularity, or more seriously, it could also fail to be continuous in the strong L^2 topology. The famous Caffarelli Kohn Nirenberg theorem on partial regularity gives an upper bound on the Hausdorff dimension of the singular set $S(T)$. We study microlocal properties of the Fourier transform of the solution in the cotangent bundle $T * (R^3)$ above this set. Our first result is that, if the singular set is nonempty, then there is a lower bound on the size of the wave front set $WF(u(T, .))$, namely, singularities can only occur on subsets of $T * (R^3)$ which are sufficiently large. Furthermore, if the solution is discontinuous in L^2 we identify a closed subset $S'(T)$ of $S(T)$ on which the L^2 norm concentrates at this time T. We then give a lower bound on the microlocal manifestation of this L^2 concentration set, which is larger than the general lower bound above. An element of the proof of these two bounds is a global estimate on weak solutions of the Navier-Stokes equations which have sufficiently smooth initial data. (Received September 08, 2013)

1096-35-682 **Jesse Ratzkin*** (jesse.ratzkin@uct.ac.za), Department of Maths and Applied Maths, University of Cape Town, Private Bag X1, Rondebosch, Cape Town, W, Cape 7701, South Africa, and **Tom Carroll** (t.carroll@ucc.ie), School of Mathematical Sciences, University College Cork, Cork, Cork , Ireland. *Isoperimetric inequalities for extremal Sobolev functions.*

I will discuss several related isoperimetric inequalities for Sobolev functions which extremize the ratio $\frac{\|\nabla u\|_{L^2}}{\|u\|_{L^p}}$, where $1 \leq p < \frac{2n}{n-2}$. On of these inequalities generalizes a family of inequalities due to Payne, Chiti, et. al, and another generalizes the classical Schwarz Lemma from complex analysis. Curiously, one inequality has a nice interpretation as a classical isoperimetric inequality for a certain conformally flat metric with singularities. (Received September 09, 2013)

1096-35-727 **Xiangjin Xu*** (xxu@math.binghamton.edu), Department of Mathematical Sciences, Binghamton University-SUNY, 4400 Vestal Parkway East, Binghamton, NY 13902. *Li-Yau type gradient estimates and a Liouville Type Theorem for the Schrördinger Operator.* Preliminary report.

In this talk, we first obtain new Li-Yau type gradient estimates for positive solutions of parabolic equations of the type

$$(\Delta_g - q(x) - \partial_t)u(x, t) = 0$$

on complete Riemmannian manifolds with nonnegetive Ricci curvature. As applications, Liouville type theorems for the Schrödinger equation

$$(\Delta_g - q(x))u(x) = 0$$

are obtained under some weaker conditions, which generalizes those results in the literature. (Received September 09, 2013)

1096-35-821 **Gung-Min Gie*** (gugie@indiana.edu), 831 E. Third St., Bloomington, IN 47405, and **James P Kelliher**, **Milton C Lopes Filho**, **Anna L Mazzucato** and **Helena J Nussenzveig Lopes**. *Vanishing viscosity limit of some symmetric flows.*

We study the boundary layers of Navier-Stokes equations at small viscosity, especially when a certain symmetry is imposed to the flow. More precisely, for the case of ill-prepared initial data, asymptotic behavior of the radially symmetric, plane-parallel, and infinite-pipe flows are discussed. Concerning such models, using the method of correctors, we prove the vanishing viscosity limit, and a version of weak convergence of Navier-Stokes vorticity to Euler vorticity up to a measure on the boundary. (Received September 10, 2013)

1096-35-862 **Susan Friedlander*** (susanfri@usc.edu) and **Walter Rusin** (walter.rusin@okstate.edu). *On the second iterate for active scalar equations.*

We consider an iterative resolution scheme for a class of active scalar equations with a fractional power of the Laplacian and focus our attention on the second iterate. In the case of critical diffusivity, we extract information relevant to well-posedness questions in scale invariant spaces. (Received September 10, 2013)

1096-35-872 **Junping Shi*** (jxshix@wm.edu), Department of Mathematics, College of William and Mary, Williamsburg, VA 23187-8795. *Bifurcation of steady state solutions of reaction-diffusion equations with nonlinear boundary conditions.*

In many chemical or biological reactions, the chemical reaction or the biological bonding occurs in a narrow layer near the boundary or on the boundary surface (cell membrane), and the nonlinear reaction on the boundary makes a nonlinear boundary condition. A unified approach for the bifurcation of non-trivial steady state solutions of scalar reaction-diffusion equations with nonlinear boundary conditions is given, and applications to several important examples are also given. This talk is based on joint work with Ping Liu and Chan-Gyun Kim. (Received September 10, 2013)

1096-35-902 **Mauricio A. Rivas*** (el_mauri_cio_alex@yahoo.com), University of Houston, Department of Mathematics, Houston, TX 77204-3008, and **Giles Auchmuty**. *Morse Index Theory and Applications to Linear Elliptic Eigenvalue Problems.*

This talk will outline the analysis of critical points of a parametrized functional that arises in the study of linear elliptic eigenvalue problems. These critical points describe the eigenvalues and eigenfunctions of the elliptic boundary value problem. The functional has well-defined second derivatives and an associated Morse index is defined that characterizes which eigenvalue is associated with the critical point. The results are exemplified for an unconstrained variational principle for Steklov eigenproblems of the Laplacian. (Received September 11, 2013)

1096-35-908 **Alexis F Vasseur*** (vasseur@math.utexas.edu). *New development of the relative entropy method applied to shocks of conservation laws.*

We will present new developments of the relative entropy method applied to the study of stability of shocks for Conservation laws. This includes, in particular, L^2 contraction up to a shift, asymptotic analysis for viscous approximations and hydrodynamical limits from kinetic equations. (Received September 11, 2013)

1096-35-917 **Leo G Rebholz*** (rebholz@clemson.edu). *Reduced order approximate deconvolution models for turbulent flows: analysis and benchmark computations.*

We propose a minor alteration of a popular Large Eddy Simulation model which lends itself to more efficient and stable numerical algorithms. We will discuss derivation of the 'new' model, some fundamental mathematical results for it, efficient and stable algorithms, and benchmark computations. (Received September 11, 2013)

1096-35-946 **Wenxian Shen** and **Xiaoxia Xie*** (xzx0005@tigermail.auburn.edu), Department of Mathematics and Statistics, Auburn University, Auburn, AL 36830. *Approximations of Random Dispersal Operators/Equations by Nonlocal Dispersal Operators/Equations.*

This paper is concerned with the approximations of random dispersal operators/equations by nonlocal dispersal operators/equations. It first proves that the solutions of properly rescaled nonlocal dispersal initial-boundary value problems converge to the solutions of the corresponding random dispersal initial-boundary value problems. Next, it proves that the principal spectrum points of nonlocal dispersal operators with properly rescaled kernels converge to the principal eigenvalues of the corresponding random dispersal operators. Finally, it proves that the unique positive stationary solutions of nonlocal dispersal KPP equations with properly rescaled kernels converge to the unique positive stationary solutions of the corresponding random dispersal KPP equations. (Received September 11, 2013)

1096-35-994 **Tarek M Elgindi***, 251 Mercer Street, New York, NY 10012, and **Frederic Rousset**.
Global Regularity for Oldroyd-B type models.

We investigate some critical models for visco-elastic flows of Oldroyd-B type in dimension two. We use a transformation which exploits the Oldroyd-B structure to prove an L^∞ bound on the vorticity which allows us to prove global regularity for our systems. (Received September 12, 2013)

1096-35-1011 **Chongsheng Cao** and **Edriss S. Titi*** (etiti@math.uci.edu), Department of Computer Science & Applied Math, Weizmann Institute of Science, 76100 Rehovot, Israel. *Regularity "in large" for the 3D Salmon's planetary geostrophic model of ocean dynamics.*

In this talk we will consider a mathematically ill-posed non-viscous planetary geostrophic model of ocean dynamics. The ill-posedness is due to the fact that the no-normal flow physical boundary condition implicitly produces an additional boundary condition for the temperature at the lateral boundary. This additional boundary condition is different, because of the Coriolis forcing term, than the no heat flux physical boundary condition. Consequently, the second order parabolic heat equation is over determined with two different boundary conditions. In a previous work we proposed one remedy to this problem by introducing a fourth-order artificial hyper-diffusion to the heat transport equation and proved global regularity for the proposed model. Another remedy for this problem was suggested by R. Salmon by introducing an additional Rayleigh-like friction term for the vertical component of the velocity in the hydrostatic balance equation. In this talk we prove the global, for all time and all initial data, well-posedness of strong solutions to the three-dimensional Salmon's planetary geostrophic model of ocean dynamics. That is, we show global existence, uniqueness and continuous dependence of the strong solutions on initial data for this model. (Received September 12, 2013)

1096-35-1017 **Constantine M. Dafermos*** (constantine_dafermos@brown.edu), Division of Applied Mathematics, Brown University, Providence, RI 02912. *Long Time Behavior of Periodic Solutions to Scalar Conservation Laws In Several Space Dimensions.*

We show that spatially periodic solutions of scalar conservation laws in several space dimensions decay to their time-invariant mean, as time tends to infinity, provided that the flux function is linearly nondegenerate just in the vicinity of the mean and in a countable family of directions. The analysis draws on the basic theory of dynamical systems and the Radon transform on a torus. (Received September 12, 2013)

1096-35-1024 **Hans G Kaper*** (kaper@mcs.anl.gov). *MPE2013 and Reaction-Diffusion Problems.*

The year 2013 was dedicated to "Mathematics of Planet Earth" (MPE2013). The dual mission of MPE2013—stimulating the mathematics research community and reaching out to the general public—was reflected in the Daily Blogs (one in English, the other in French), each of which featured some 300 posts on a wide variety of topics, ranging from conference announcements and workshop reports to short articles on topics from astronomy to uncertainty quantification. In this talk I will discuss some of the posts on problems involving reaction-diffusion equations and their relevance for the MPE themes. (Received September 12, 2013)

1096-35-1035 **Dipendra Regmi*** (dregmi1@uco.edu), Department of Mathematics and Statistics, University of Central Oklahoma, Edmond, OK 73034. *A Study on the Global Regularity for Two-dimensional Magnetohydrodynamic Equations.*

We study the global regularity of classical solutions to the 2D incompressible magnetohydrodynamic (MHD) equations with horizontal dissipation and horizontal magnetic diffusion. We establish a global bound for the horizontal components in any Lebesgue space L^{2r} with $1 \leq r < \infty$ and grows no faster than the order of $\sqrt{r \log r}$ as r increases. By applying the logarithmic bound for horizontal components together with the Besov Space technique, we prove the global regularity of the MHD equations with horizontal dissipation and horizontal magnetic diffusion. This is a joint work with C. Cao, J. Wu, and X. Zheng. (Received September 12, 2013)

1096-35-1057 **G. Kanschat**, Im Neuenheimer feld 368, 69120 Heidelberg, Germany, and **Natasha S. Sharma*** (natasha.sharma@iwr.uni-heidelberg.de), Im Neuenheimer Feld 368, 69120 Heidelberg, Germany.
A cochain complex for interior penalty methods: error estimates and multigrid through differential relations.

In this talk, we discuss the differential relation between divergence-conforming discontinuous Galerkin methods for the Stokes system and continuous interior penalty schemes for the biharmonic problem. We show that this relation can be exploited to transfer results on multigrid methods and on error estimates between the two schemes. In numerical examples, we demonstrate the efficiency of the methods obtained through these relations. (Received September 12, 2013)

1096-35-1058 **Silvia Jimenez Bolanos*** (sjimenez@colgate.edu) and **Bogdan Vernescu**. *Nonlinear Neutral Inclusions: Assemblages of Confocal Coated Spheres and Ellipsoids.*

If a neutral inclusion is inserted in a matrix containing a uniform applied electric field, it does not disturb the field outside the inclusion. The well known Hashin coated sphere is an example of a neutral coated inclusion. In this talk, we consider the problem of constructing neutral inclusions from nonlinear materials. In particular, we discuss assemblages of coated spheres and ellipsoids. (Received September 12, 2013)

1096-35-1086 **Dionisios Margetis*** (dio@math.umd.edu), 2106 Mathematics Building, Department of Mathematics, University of Maryland, College Park, MD 20742, and **Kanna Nakamura** (nakamura@math.umd.edu), 4400 Mathematics Building, Department of Mathematics, University of Maryland, College Park, MD 20742. *Homogenization of composite vicinal surfaces in 1+1 dimensions.*

We formally apply classical homogenization to derive macroscopic relaxation laws for crystal surfaces with distinct inhomogeneities at the microscale. The proposed method relies on a multiscale expansion in one spatial coordinate. The starting point is the Burton-Cabrera-Frank (BCF) model for the motion of line defects (steps) separating nanoscale terraces. We enrich this model with sequences of distinct material parameters, i.e., disparate diffusivities of adsorbed atoms (adatoms) across terraces, kinetic sticking rates at step edges, and step energy parameters for elastic-dipole interactions. Multiscale expansions for the adatom concentration and flux are used, with a slow diffusive time scale consistent with the quasi-steady regime for terrace diffusion. The ensuing macroscopic, nonlinear evolution laws incorporate averages of the microscale parameters. (Received September 12, 2013)

1096-35-1095 **Jian-Guo Liu*** (jliu@math.duke.edu), Department of Mathematics, Duke University, Durham, NC 27708, and **Frederic Coquel**, **Shi Jin** and **Li Wang**. *Singular limit of a nonlinear hyperbolic system with a two-scale relaxation parameter at an interface.*

In this talk, I will present a rigorous convergence analysis of a nonlinear hyperbolic system with a two-scale relaxation parameter at an interface. In the right part of the interface, the relaxation parameter is vanishing and we recover in the limit the underlying equilibrium PDEs, while in the left part, we deal with a finite relaxation rate. A relaxation layer develops within the interface in the asymptotic regime. Its Kruzkov like entropy analysis reveals the matching conditions in between the left and right PDEs models. The limit solution is proved to be bounded in sup norm with bounded total variation and the interface layer is monotone. (Received September 12, 2013)

1096-35-1097 **Hijun Choe** and **Minsuk Yang*** (yangm@kias.re.kr), 85 Hoegi-ro Dongdaemun-gu, Seoul 130-722, South Korea, South Korea. *Partial regularity of weak solutions to the imcompressible magnetohydrodynamic equations.*

We study the local behavior of the solutions to the three-dimensional magnetohydrodynamic (MHD) equations. The equations describe MHD are a combination of the Navier-Stokes equations of fluid dynamics and Maxwell's equations of electromagnetism. We prove the localized enegy estimates, Biot-Savart law, and interpolation inequality. By combining and iterating those estimates, we prove partial regularity of weak solutions. By the similar scheme, we also investigate the Hausdorff dimension of the singular set. (Received September 12, 2013)

1096-35-1108 **Alexey Miroshnikov** and **Konstantina Trivisa*** (trivisa@math.umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742. *Relaxation approximations to hyperbolic balance laws.*

A general framework is presented for the approximation of systems of hyperbolic balance laws. The novelty of the analysis lies on the construction of suitable relaxation systems and the derivation of a delicate estimate on the relative entropy. A direct proof of convergence before the formation of shocks is provided for a wide class of physical systems arising in materials science. Our analysis is in the spirit of the framework introduced by Tzavaras (2005) for systems of hyperbolic conservation laws. (Received September 13, 2013)

1096-35-1110 **Donatella Donatelli** and **Konstantina Trivisa*** (trivisa@math.umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742. *On a nonlinear model for tumor growth: Global in time weak solutions.*

We investigate the dynamics of a class of tumor growth models known as mixed models. The key characteristic of these type of tumor growth models is that the different populations of cells are continuously present everywhere in the tumor at all times. In the present article we focus on the evolution of tumor growth in the presence of proliferating, quiescent and dead cells as well as a nutrient. The system is given by a multi-phase flow model and the tumor is described as a growing continuum Ω with boundary $\partial\Omega$ both of which evolve in time. Global-in-time weak solutions are obtained using an approach based on penalization of the boundary behavior, viscosity and the pressure in the weak formulation. (Received September 13, 2013)

1096-35-1128 **Jean Marcel Fokam*** (fokam@aun.edu.ng), School of Arts and Sciences, American Univers, University of Nigeria, Yola, 2250, Nigeria. *Multiplicity and regularity of large periodic solutions with rational frequency for a class of semilinear monotone wave equations.*

We prove the existence of infinitely many classical large periodic solutions for a class of semilinear wave equations with periodic boundary conditions:

$$u_{tt} - u_{xx} = f(x,u),$$
$$u(0,t) = u(\pi,t)\ \ , u_x(0,t) = u_x(\pi,t).$$

Our argument relies on some new estimates for the linear problem with periodic boundary conditions, the Hausdorff-Young theorem of harmonic analysis and a variational formulation due to, Rabinowitz for the corresponding Dirichlet problem.

(Received September 13, 2013)

1096-35-1136 **C. David Levermore*** (lvrmr@math.umd.edu). *Dispersive Navier-Stokes Systems for Gas Dynamics.*

The Navier-Stokes system for gases fail to capture the correct dynamics in all fluid regimes. The correct dynamics can be recovered by the addition of quasi-linear dispersive terms, leading to the so-called dispersive Navier-Stokes system. We will present the kinetic origins of these systems and a local well-posedness result. Dispersive regularity is used to control the new terms. The second result is joint with Weiran Sun. (Received September 13, 2013)

1096-35-1144 **Mathew R Gluck*** (mgluck@ufl.edu), 358 Little Hall, PO box 118105, Gainesville, FL 32611, and **Ying Guo** and **Lei Zhang**. *A Harnack-Type Inequality for a Prescribing Curvature Equation on a Domain with Boundary.*

In this paper we use the method of moving spheres to derive a Harnack-type inequality for positive solutions of

$$\begin{cases} \Delta u + K(x)u^{(n+2)/(n-2)} = 0 & x \in B_1^+ \subset \mathbb{R}^n_+ \\ \frac{\partial u}{\partial x_n} = c(x)u^{n/(n-2)} & x \in \partial B_1^+ \cap \partial\mathbb{R}^n_+, \end{cases}$$

where $n \geq 4$, $\mathbb{R}^n_+$ is the upper half-space and B_1^+ is the upper half unit ball. Under suitable assumptions on $K(x)$ and $c(x)$, we show that there is a positive constant C such that for all positive solutions u, a Harnack type inequality holds. As a consequence of this inequality we obtain the following energy estimate

$$\int_{B^+_{1/2}} \left(u^{\frac{2n}{n-2}} + |\nabla u|^2\right)\, dx \leq C.$$

(Received September 13, 2013)

1096-35-1165 **Kalea A Sebesta*** (k_sebesta@yahoo.com), 200 Talus Way, Apt 212, Reno, NV 89503. *Nucleation in a Two Component Metal Alloy and the Corresponding Boundary Conditions.* Preliminary report.

This is a numerical study that explores the phase separation phenomenon, known as nucleation, specifically in a two component metal alloy. The aim of this study is to understand the change in the number of components both as a function of time and a function of parameters. In order to accomplish this, numerical topology code to find the number of components was developed and analysis was used to develop some heuristic arguments. For the purpose of this research, a stochastic equation was used implying, that there are necessarily large deviations in behavior in an individual run. Therefore, it was necessary to perform and average a large number of simulations to see the full scope of the behavior. These arguments paved way for predictions of the expected behavior both in time and in parameter variation. Furthermore, the stochastic behavior is what gave rise to the predictions for how the behavior should change in time. The results are based on the theory of large deviations which say that the time to nucleation should depend on the largest eigenvalue. (Received September 13, 2013)

1096-35-1172 **Siddhartha Mishra*** (smishra@sam.math.ethz.ch), ETH HG G 57.2, Raemistrasse 101, 8092 Zurich, Switzerland. *Numerical schemes that converge to the entropy measure valued solutions of systems of conservation laws.*

Entropy solutions are considered to be the correct notion of solutions for hyperbolic systems of conservation laws. We question this notion through illustrative numerical experiments in several space dimensions and demonstrate that entropy solutions may not be well-posed. On the other hand, numerical experiments suggest that the solutions maybe young measures and the appropriate solution framework is that of entropy measure valued solutions. We develop a general theory for obtaining numerical schemes that converge to entropy measure valued solutions and provide at least two classes of numerical methods that satisfy these abstract criteria. We conclude with a discussion of interesting theoretical as well as computational issues that arise in this context. (Received September 13, 2013)

1096-35-1221 **Emil Wiedemann*** (emil@math.ubc.ca). *Non-uniqueness and boundary effects for the incompressible Euler equations.*

In their recent ground-breaking work, C. De Lellis and L. Székelyhidi showed that the Cauchy problem for the incompressible Euler equations is ill-posed in the framework of weak solutions, even when various further assumptions on the energy are made. I will present some new results in this direction, including the construction of non-dissipative energy solutions in bounded domains, and conceivable selection criteria for weak solutions. (Received September 13, 2013)

1096-35-1233 **Irena Lasiecka*** (lasiecka@memphis.edu). *Long time behavior of flow-structure interaction without mechanical dissipation.*

We consider a PDE model consisting of a nonlinear plate immersed in a flow of gas moving through 3-d space with a supersonic velocity. The latter is described by the so called modified wave equation whose resolvent exhibits the loss of ellipticity.

The goal is to study long time behavior of the resulting interaction. It is shown that structural solutions (solutions to the plate equation) converge asymptotically to an attracting set which is both finite dimensional and smooth. The converge is uniform with respect to the topology induced by finite energy.

In contrast with other works on the subject, the result described holds (i) without imposing any dissipation on the structure and (ii) without assuming an existence of smoothing effects within the structure (such as thermoelasticiy , structural damping or rotational inertia). The proof is based on taking an advantage of (1) "hidden regularity" associated with the delay term describing the effect of the flow, (2) natural dispersive effects associated with the flow which translate into "hidden" dissipation affecting the structure. (Received September 13, 2013)

1096-35-1243 **Zaher Hani***, 251 Mercer Street, New York, NY 10012. *Wave turbulence closures and limits.* Preliminary report.

Wave turbulence seeks a statistical description of the out-of-equilibrium dynamics of nonlinear dispersive equations. The derivations of weak turbulence equations (aka closures) are still far from rigorous. We will discuss some recent steps towards better understanding the various limits involved in the formal derivation. The talk is based on collaborations with E. Faou, I. Gallagher and P. Germain. (Received September 13, 2013)

1096-35-1248 **Nguyen H Lam*** (nguyenlam@wayne.edu), 656 W. Kirby, 1118 FAB, Detroit, MI 48202. *Recent development on sharp Moser-Trudinger-Adams type inequalities.*

In this talk, we will present some recent development on sharp Moser-Trudinger type inequalities on first order Sobolev spaces and Adams type inequalities on high order Sobolev spaces on both Euclidean spaces and Heisenberg groups. Since the symmetrization argument is not available on these settings, we will propose a rearrangement-free method to study these sharp inequalities. These are joint works with Guozhen Lu. (Received September 13, 2013)

1096-35-1258 **Cyril Joel Batkam*** (cyril.joel.batkam@usherbrooke.ca), 2500 Boul. de l'Université, Sherbrooke, Quebec J1K2R1, Canada. *Multiplicity result for a class of elliptic systems.* Preliminary report.

We consider a class of elliptic systems which lead to the study of strongly indefinite symmetric functionals, and with nonlinearities which do not satisfy the Ambrosetti-Rabinowitz super-quadratic condition. Since in the case we consider we do not know whether the functionals satisfy the Palais-Smale condition, we develop two generalized versions of the Symmetric Mountain Pass Theorem in order to prove the existence of infinitely many solutions. The first version is based on the monotonicity trick and the second uses the Cerami condition. (Received September 14, 2013)

1096-35-1265 **Paul Cazeaux*** (cazeaux@ann.jussieu.fr), 4 Place Jussieu, 75010 Paris, France, and **Celine Grandmont** (celine.grandmont@inria.fr). *A mathematical homogenized model for the mechanical behavior of the lungs' parenchyma.*

We are interested in the mathematical modeling of the deformation of the human lung tissue, called the lung parenchyma, during the respiration process. The parenchyma is a foam-like elastic material containing millions of air-filled alveoli connected by a tree-shaped network of airways. In this model, the parenchyma is governed by the linearized elasticity equations and the air movement in the tree by the Poiseuille law in each airway. The geometric arrangement of the alveoli is assumed to be periodic with a small period $\varepsilon > 0$. We use the two-scale convergence theory to study the asymptotic behavior as ε goes to zero. The effect of the network of airways is described by a nonlocal operator and we propose a simple geometrical setting for which we show that this operator converges. We identify in the limit the equations modeling the homogenized behavior under an abstract convergence condition on this nonlocal operator. We derive some mechanical properties of the limit material by studying the homogenized equations: the limit model is nonlocal both in space and time if the parenchyma material is considered compressible, but only in space if it is incompressible. Finally, we propose a numerical method to solve the homogenized equations. (Received September 14, 2013)

1096-35-1294 **Long Chen*** (chenlong@math.uci.edu), 510 F Rowland Hall, Irvine, CA 92617, and **Jack Xin** and **Penghe Zu**. *Numerical Study of KPP Equation.*

In this talk we consider the traveling front speed of Kolmogorov-Petrovsky-Piskunov(KPP) equation with steady or unsteady flows. We use stabilized finite element methods (FEM) and spectral methods (SM) to find approximations of the KPP equation. We verify that the relation between the minimal traveling front and the amplitude of flow function, and furthermore show the existences of the residual diffusion for unsteady flows. We combine FEM and SM to improve the efficiency of the algorithm, and apply a fast solver to speed up the simulation. (Received September 14, 2013)

1096-35-1296 **Georg Hetzer*** (hetzege@auburn.edu), Department of Mathematics and Statistics, 304 Parker Hall, Auburn University, Auburn, AL 36849-5310. *Diffusion-Driven Instability.*

The concept of diffusion-driven instability goes back to Turing who proposed it as a mechanism for pattern formation. In terms of reaction-diffusion systems Turing instability occurs if a stable spatially homogeneous equilibrium in the absence of diffusion becomes unstable in the presence of diffusion. The main part of the talk will focus on results of joint work with A. Madzvamuse and Wenxian Shen for the case of evolving domains. Our approach relies on transforming the original system into a reaction-diffusion system on a fixed domain with time-dependent diffusion coefficients and non-autonomous reaction terms and to employ Lyapunov exponents for establishing Turing conditions. Some work in progress will be mentioned at the end of the talk. (Received September 14, 2013)

1096-35-1323 **Chi Hin Chan** and **Magdalena Czubak*** (czubak@math.binghamton.edu). *Uniqueness questions for the Navier-Stokes equation in the hyperbolic setting.*

The smoothness and uniqueness of the Leray-Hopf solutions for the Navier-Stokes equations is well-known in 2D. Contrary to what is known in the Euclidean setting, in our previous work we showed that there is non-uniqueness in 2D for simply connected manifolds with negative sectional constant curvature. The goal of this talk is to show how we can restore uniqueness. In the process, we develop the theory of weak solutions to the Navier-Stokes equations on the 2D hyperbolic space. (Received September 14, 2013)

1096-35-1328 **Aghalaya S Vatsala*** (vatsala@louisiana.edu), Department of Mathematics, University of Louisiana at Lafayette, Lafayette, LA 70504-1010, and **Donna Sue Stutson**. *Sub and Super Hyperbolic Linear Partial Fractional Differential Equations with Numerical Results.* Preliminary report.

We obtain a representation form for the sub and super hyperbolic Caputo fractional partial differential equations in one dimensional space with initial and boundary conditions. The solution obtained will depend on the initial condition, boundary conditions and the nonhomogeneous terms and the value of q as well. We consider both the situations when the equation is qth order in the time variable, especially when, 1<q¡2, and 2<q¡3. For q=2, it reduces to second order hyperbolic equation. The software MAPLE 16 is used to graphically represent solutions to some linear sub hyperbolic Caputo fractional partial differential equations in one dimensional space. (Received September 14, 2013)

1096-35-1393 **Clark Musselman*** (clark@simons-rock.edu), 84 Alford Rd, Gt Barrington, MA 01230, and **Jeffrey Schenker**. *Higher Moments for a Markov-Schrödinger Wave Equation on a Lattice.*

We consider the long time evolution of solutions ψ_t to a Markov-Schrödinger wave equation on a lattice. Specifically, we focus on the computation of moments of the position variable with respect to the probability density function $\mathbb{E}(|\psi_t|^2)$ on $\mathbb{Z}^d$. We show that the diffusive scaling of moments of position $|x|^p \sim t^{p/2}$ is observed. (Received September 15, 2013)

1096-35-1409 **Maya Chhetri*** (maya@uncg.edu), Department of Mathematics and Statistics, UNC Greensboro, Greensboro, NC 27402, and **Petr Girg**. *Local behavior of Continua of Solutions for Asymptotically Linear Systems.*

We consider an elliptic system of the form

$$\left.\begin{array}{r} -\Delta u = \lambda\theta_1 a(x)v + f(\lambda, x, v) \quad \text{in} \quad \Omega \\ -\Delta v = \lambda\theta_2 a(x)u + g(\lambda, x, u) \quad \text{in} \quad \Omega \\ u = 0 = v \quad \text{on} \quad \partial\Omega\,, \qquad\qquad \end{array}\right\}$$

where $\lambda \in R$ is a parameter, $\theta_1, \theta_2 > 0$, $a(x) \in L^\infty(\Omega)$, $a(x) \geq 0$ a.e. in Ω and Ω is a bounded domain in R^N with $C^{2,\alpha}$-boundary $\partial\Omega$. Here $f, g : R \times \Omega \times R \to R$ are Carathéodory functions that are either sublinear at infinity or bounded. We provide sufficient conditions for determining the λ-direction in which a continuum of positive solutions emanates from infinity at the first eigenvalue of associated linear problem. (Received September 15, 2013)

1096-35-1412 **Durga Jang KC*** (kcdurga@math.okstate.edu), MS 401, Oklahoma State University, Stillwater, OK 74078. *Generalized 2D Euler-Boussinesq equations with a singular velocity.* Preliminary report.

We establish the global existence and uniqueness of solutions to the initial-value problem of a system of equations generalizing the two-dimensional Boussinesq equations when the velocity is "double logarithmically" more singular than the one given by the Biot-Savart law. This global regularity result go beyond the critical case. This is the joint work with D. Regmi, L. Tao and J. Wu. (Received September 15, 2013)

1096-35-1428 **Robert Pertsch Gilbert*** (gilbert@math.udel.edu), 112 Briar Lane, Newark, DE 19711, and **Alexander Panchenko** and **Ana Vasilic**. *Biphasic Acoustic Behavior of a Non-periodic Porous Medium.*

We study the problem of derivation of an effective model of acoustic wave propagation in a two-phase, non-periodic medium modeling a fine mixture of linear elastic solid and a viscous Newtonian fluid. Bone tissue is an important example of a composite material that can be modeled in this fashion. We extend known homogenization results for periodic geometries to the case of a stationary random, scale-separated microstructure. The ratio ε between a typical size of microstructural inhomogeneity and the macroscopic length scale is a small parameter of the problem. We employ stochastic two-scale convergence in the mean to pass in the limit to the governing equations. The effective model describes a biphasic viscoelastic material with long time history dependence. Homogenized system describes macroscopically anisotropic media and appears to be more general than the Biot system; however, numerical realizations show that the *non-Biot* coefficients are much smaller than the usual Biot coefficients. Hence, we obtain a numerical scheme for accurately determining the Biot coefficients. (Received September 15, 2013)

1096-35-1460 **Nathan Glatt-Holtz**, **Igor Kukavica**, **Vlad Vicol*** (vvicol@math.princeton.edu) and **Mohammed Ziane**. *Existence and regularity of invariant measures for the three dimensional stochastic primitive equations.*

We establish novel moment bounds for strong solutions of the stochastic 3D Primitive Equations. Using these bounds we establish the continuity of the associated Markovian semigroup and prove the existence of an invariant measure associated to these equations. This measure is supported on strong solutions, but is furthermore shown to have higher regularity properties. (Received September 15, 2013)

1096-35-1468 **Peter Constantin** (const@math.princeton.edu) and **Vlad Vicol*** (vvicol@math.princeton.edu). *Nonlinear lower bounds for linear nonlocal operators.*

We introduce a new lower bound for linear nonlocal operators such as the fractional Laplacian. Taking into account a given a priori estimate, available say for the solution of a PDE, this lower bound becomes nonlinear. As an application we prove the global existence of smooth solutions for critical and subcritical advection-diffusion equations. (Received September 15, 2013)

1096-35-1471 **Zhiliang Xu*** (zxu2@nd.edu), ACMS Department, Notre Dame, IN 46556.
Divergence-Free WENO Reconstruction-Based Finite Volume Scheme for Solving Ideal MHD Equations on Triangular Meshes.

We introduce a high-order accurate constrained transport type nite volume method to solve ideal magnetohydrodynamic equations on two-dimensional triangular meshes. A new divergence-free WENO-based reconstruction method is developed to maintain exactly divergence-free evolution of the numerical magnetic field. Moreover, for two reconstructed approximations to the exact magnetic field supported on two grid cells sharing a common edge, the normal contributions of these two reconstructed approximations in the edge unit normal direction match exactly on the edge. Additionally, a new weighted flux interpolation approach is also developed to compute the z-component of the electric fi eld at vertices of grid cells. We also present numerical examples to demonstrate the accuracy and robustness of the proposed scheme. (Received September 15, 2013)

1096-35-1512 **Daniele Garrisi*** (daniele.garrisi@gmail.com), West Building, Office No. 443, Department of Mathematics Education, Inha University, Incheon, 402751, South Korea, and **Vladimir Georgiev**, Dipartimento di Matematica "Leonida Tonelli", Largo Bruno Pontecorvo n. 5, 56127 Pisa, Pisa, Italy. *Traveling-wave solutions to the half-wave equation.* Preliminary report.

We discuss the existence of traveling-wave solutions

$$\psi(t,x) = e^{-i\omega t}\phi(x-tv) \tag{1}$$

to evolution equation

$$i\partial_t\psi - \sqrt{-\Delta}\,\psi + |\psi|^{p-1}\psi - |\psi|^{q-1}\psi = 0, \quad 1 < p < q \tag{2}$$

in spatial dimension $N = 1$ and for velocities v such that $|v| < 1$. The existence of such solutions can be obtained by showing that minimising sequences of the energy functional

$$\mathcal{E}\colon H^{1/2}(\mathbb{R}) \to \mathbb{R}$$

$$\mathcal{E}(\phi) = H_v(\phi) - \frac{1}{p+1}\|\phi\|_{p+1}^{p+1} + \frac{1}{q+1}\|\phi\|_{q+1}^{q+1}$$

$$H_v(\phi) = \frac{1}{2}\|\phi\|^2_{\dot{H}^{1/2}(\mathbb{R})} + \frac{i}{2}\int_{-\infty}^{+\infty}\nabla\phi(x)\cdot v\overline{\phi}(x)dx$$

over the constraint

$$S(\lambda) = \{\phi \in H^{1/2}(\mathbb{R}) \mid \|\phi\|^2_{L^2} = \lambda\}$$

exhibit a concentration-compactness behaviour. The concentration-compactness, along with other features of positive solutions to (**??**), is an essential premise to the proof of the orbital stability of the solutions in (1). (Received September 16, 2013)

1096-35-1515 **Svetlana Roudenko*** (roudenko@gwu.edu), Washington, DC 20052. *On thresholds for scattering and blow up in the nonlinear Schroedinger equation.* Preliminary report.

We consider the nonlinear Schroedinger equation with finite energy, finite variance initial data in the energy subcritical, critical and supercritical cases and discuss thresholds for scattering and blow-up. In particular, we discuss the global behavior of the modulated ground state. This is a joint work with Thomas Duyckaerts. (Received September 16, 2013)

1096-35-1521 **Stephen Robinson*** (sbr@wfu.edu), 2243 Winterberry Dr, Winston Salem, NC 27106, and **Pavel Drabek**. *Resonance problems with respect to the Fucik Spectrum.*

We consider the boundary value problem

$$-\Delta u = \alpha u^+ - \beta u^- + g(u) + h \text{ in } \Omega, u = 0 \text{ on } \partial\Omega,$$

where Δ is the Laplace operator, (α, β) is in the Fucik Spectrum, $g : R \to R$ is bounded and continuous, and Ω is a bounded domain in R^n. We prove an existence theorem subject to a Landesman-Lazer type condition on the primitive of g. The proof relies on a variational characterization of the Fucik Spectrum due to Castro and Chang. (Received September 16, 2013)

1096-35-1556 **Jerome Goddard II*** (jgoddard@aum.edu) and **R. Shivaji** (shivaji@uncg.edu).
Diffusive logistic equation with constant yield harvesting and negative density dependent emigration on the boundary.

The structure of positive steady state solutions of a diffusive logistic population model with constant yield harvesting and negative density dependent emigration on the boundary is examined. In particular, a class of nonlinear boundary conditions that depends both on the population density and the diffusion coefficient is used to model the effects of negative density dependent emigration on the boundary. In this presentation, we discuss existence results established via the well-known sub-super solution method. (Received September 16, 2013)

1096-35-1590 **Mihalis Dafermos*** (m.dafermos@dpmms.cam.ac.uk), Department of Mathematics, Fine Hall, Washington Road, Princeton, NJ, and **Gustav Holzegel** and **Igor Rodnianski**. *A scattering theory construction of dynamical vacuum black hole spacetimes.*

This talk will outline a construction of dynamical vacuum black hole spacetimes in general relativity. These spacetimes settle down asymptotically to a member of the Kerr family, and are parameterised by scattering data encoding gravitational radiation radiated to infinity, or to the black hole. These spacetimes constitute the first known examples of vacuum metrics exhibiting this behaviour. (Received September 16, 2013)

1096-35-1611 **chongsheng cao***, Department of Mathematics, Florida International University, Miami, FL 33199. *2D Boussinesq equations and 2D MHD equations.*

We consider the 2D Boussinesq equations and MHD equations. We will show the results about the global regularity under different dissipation schemes. (Received September 16, 2013)

1096-35-1641 **Nathan Glatt-Holtz** and **Roger Temam** (wang211@umail.iu.edu), Blooimgton, IN 47408, and **Chuntian Wang*** (wang211@umail.iu.edu), Rawles Hall, 831 East 3rd St, Bloomington, IN 47405. *A Hyperbolic Model from Plasma Physics: The Zakharov-Kuznetsov Equation.*

The Zakharov-Kuznetsov (ZK) equation, a model arising from plasma physics, is a 2 or $3D$ wave equation of the family of the Korteweg-de Vries (KdV) equations. Recently the ZK equation has attracted considerable attention because it is closely related with the physical phenomena and contributes to the understanding of more general problems that are partly hyperbolic (such as the inviscid primitive equations).

In this talk, we present some recent mathematical results concerning the ZK equation in a bounded domain motivated by the study of boundary control problems. New difficulties arise; firstly, the linear operator associated with this model is neither symmetric nor coercive and has an anisotropic structure. Secondly, new technical tools have been developed to deal with the boundary conditions. Thirdly the proof of uniqueness of weak solutions provides an idea of how to deal with the lack of regularity of the difference of the solutions.

We will also discuss recent works of extending the ZK equation to the stochastic case, in the effort of capturing more realistic physical phenomena.

These are the joint works with R. Temam, N. Glatt-Holtz and J-C. Saut.
(Received September 16, 2013)

1096-35-1665 **Avner Friedman** and **King-Yeung Lam*** (lam.184@osu.edu), 3rd Floor Jennings Hall, 1735 Neil Ave, Columbus, OH 43210. *Are Small Granulomas Stable?*

We consider a free-boundary problem for a system of two semi linear parabolic equations. The system represents a simple model of granuloma, a collection of immune cells and bacteria filling a 3-dimensional domain which varies with time. We prove the existence of stationary spherical solutions and study their linear stability. This gives a mechanistic explanation to the experimentally observed critical size of granulomas leading to active disease state. (Received September 16, 2013)

1096-35-1675 **Eitan Tadmor***, Ctr for Scientific Computation and Math Model, CSCAMM, CSIC Bldg. #406, University of Maryland, College Park, MD 20742. *On variational formulation of entropy solutions to nonlinear conservation laws.*

A proper notion of weak solutions for nonlinear conservation laws requires such solutions to be *entropic*. Classical and more recent results show the important role that entropy plays in the analysis and computation of stable solutions. Entropy solutions are found to be at the crossroads when reached from a microscopic kinetic formulation or from a macroscopic realization as vanishing viscosity limit. In both cases, entropy solutions were also interpreted within a proper variational framework.

The notion of entropy, which is intimately connected with symmetry, is an extension imposed on nonlinear systems conservation laws. In this context, K. O. Friedrichs in his 1979 John von Neumann Lecture, asked

> "Now, in many branches of physics ... symmetries play a fundamental role, but all these symmetries—as it seems to me—are assumed and not derived. I now wonder whether or not ... symmetries can also be derived."

In this lecture I will give a concise overview on the theory and computation of entropy solutions for nonlinear conservation laws, and I will present a new variational formulation which addresses the question raised by Friedrichs. (Received September 16, 2013)

1096-35-1692 **Pierre-Emmanuel Jabin*** (pjabin@umd.edu) and **Denis Talay**. *Reduction in complexity in Multi-agents models.*

We consider a certain number of economical agents, each described by a random variable and solving a system of Stochastic Differential Equations coupled through a mean field interaction. Some coefficients in the coupled system are optimized by a centralized authority (central bank, government) in order to maximize the average utility. Solving this system would thus require the resolution of a N-dimensional visquous Hamilton-Jacobi equation which far too costly computationally. Instead, we derive a 1 dimensional coupled system giving a good approximation. (Received September 16, 2013)

1096-35-1706 **Xuwen Chen** and **Justin Holmer*** (holmer@math.brown.edu), Brown University, Box 1917, 151 Thayer St, Providence, RI 02912. *Derivation of the 1D focusing nonlinear Schrödinger equation from quantum many-body dynamics.*

We consider the dynamics of N bosons in one dimension. We assume that the pair interaction is attractive and given by $N^{\beta-1}V(N^{\beta}\cdot)$ where $\int V \leqslant 0$. We develop new techniques in treating the $N-$body Hamiltonian so that we overcome the difficulties generated by the attractive interaction and establish new energy estimates. We also prove the optimal 1D collapsing estimate which reduces the regularity requirement in the uniqueness argument by half a derivative. We derive rigorously the one dimensional focusing cubic NLS with a quadratic trap as the $N \to \infty$ limit of the N-body dynamic and hence justify the mean-field limit and prove the propagation of chaos for the focusing quantum many-body system. (Received September 16, 2013)

1096-35-1747 **Virgil U Pierce*** (piercevu@utpa.edu), University of Texas – Pan American, 1201 W University Drive, Edinburg, TX 78539. *Dispersionless limits of Hirota equations for map enumeration.*

The Hirota equations of the Toda lattice hierarchy express the conditions satsified by the tau functions generating solutions to the hierarchy. The tau functions for special initial conditions have combinatoric meaning, coming from the partition function of random matrices for the Gaussian unitary ensemble, their asymptotic expansion gives generating functions for the enumeration of maps (or ribbon graphs) partitioned by genus. The asymptotic expansion of the tau functions induces a dispersionless limit on the Hirota equations which can then be used to determine the precise structure of the generating functions. For example in some cases we find explicit formulas for the generating functions. We will give some of the progress being made on this enumeration problem, including symmetry results and connections with non-orientable generalizations coming from the Hirota equations for the Pfaff lattice hierarchy. (Received September 16, 2013)

1096-35-1757 **Saber Trabelsi*** (saber.trabelsi@kaust.edu.sa), 4700, King Abdullah University of Science and, Technology, Mail Box No: 4206, Thuwal, Jeddah, 23955-6900, Saudi Arabia. *The Multi-Configuration Time Dependent Hartree-Fock Equations.*

The multi-configuration methods are a natural generalization of well-known simple models for approximating the linear N body Schrödinger equation, like the Hartree and the Hartree-Fock models of molecular dynamics. Models like MCTDHF are intensively used by physicists and chemists for numerical simulations in physics/quantum chemistry. However, from the mathematical point of view, these models are yet not well understood. In this talk, we formulate the MCTDHF equations of motion in a suitable way for the mathematical analysis of the associated initial value problem. Next, we present local existence and uniqueness results in the energy space and in L^2. Eventually, we show that the solution is actually global whenever the initial data satisfies a particular energy criterion. (Received September 16, 2013)

1096-35-1761 **Seungly Oh*** (ohseun@missouri.edu), Room 217, Mathematical Sciences Building, University of Missouri - Columbia, Columbia, MO 65211. *Non-linear effect in the periodic KdV equation with rough initial data.*

We observe a smoothing effect of global-in-time solutions of the periodic Korteweg-de Vries equation in low regularity settings $H^{-1/2+}$. This smoothing effect is given by subtracting off a non-linear resonant solution, rather than the linear solution. The main method involved is the normal form transform. The result indicates a strong non-linear effect arising in the solution dynamics when the initial data contains rapid oscillations. (Received September 16, 2013)

1096-35-1783 **Jyoti Saraswat*** (jyo1@umbc.edu), 1000 Hilltop Circle, Department of Mathematics and Statistics, University of Maryland, Baltimore County, Baltimore, MD 21228, and **Andrei Draganescu** (draga@umbc.edu), 1000 Hilltop Circle, Department of Mathematics and Statistics, University of Maryland, Baltimore County, Baltimore, MD 21228. *Multigrid Solution of Distributed Optimal Control Problems Constrained by Semilinear Elliptic Pdes.*

We study a multigrid solution strategy for distributed optimal control problems constrained by semilinear elliptic PDEs. Working in the discretize-then-optimize framework, we solve the reduced optimal control problem using Newton's method. Further, adjoint methods are used to compute matrix-vector multiplications for the reduced Hessian. In this work we introduce and analyze a matrix-free multigrid preconditioner for the reduced Hessian which proves to be of optimal order with respect the discretization. (Received September 16, 2013)

1096-35-1815 **Yuliya Gorb*** (gorb@math.uh.edu), 636 PGH, Department of Mathematics, University of Houston, Houston, TX 77204-3008, **Dmitri Kuzmin** (kuzmin@am.uni-erlangen.de), Institute of Applied Mathematics III, University Erlangen-Nuremberg, Cauerstr. 11, D-91058, Erlangen, Germany, and **Otto Mierka** (omierka@mathematik.uni-dortmund.de), Institute of Applied Mathematics III, Dortmund University of Technology, Vogelpothsweg 87, D-44227, Dortmund, Germany. *Finite element simulation of laminar three-dimensional particulate flows.*

This talk focuses on the modeling of buoyancy effects and effective viscosities in mixture models of particle-laden incompressible fluids. The generalized Navier-Stokes system and the continuity equation for the volume fraction of the disperse phase are discretized using a finite element method, and monotonicity constraints are enforced using algebraic flux correction. A numerical study is performed for the laminar flow of dilute, semi-dilute, and concentrated suspensions over a three-dimensional backward-facing step and driven cavity. (Received September 16, 2013)

1096-35-1860 **David Kinderlehrer*** (davidk@andrew.cmu.edu), Dept.of Mathematical Sciences, Wean Hall, Carnegie Mellon University, Address 1, Pittsburgh, PA 15213. *Monge-Kantorovich mass transport for modeling systems and solving partial differential equations and systems.*

Questions in transport arising from cell biology and in chemistry present novel issues when modeled using mass-transport paradigms. A particular situation is that the equilibrium configuration does not correspond to an energy minimizer and thus the solution is not governed by a conventional entropy principal. Can we approach this in a physically meaningful way that also leads to the solution of the problem and in addition to the characterization of transport properties we expect the solution to have? We discuss these and other issues. (Received September 16, 2013)

1096-35-1872 **Xiaoyi Zhang*** (xiaozhang@math.uiowa.edu), **Monica Visan** and **Rowan Killip**. *Global well-posedness and scattering for focusing cubic NLS on the exterior of strictly convex obstacle in three dimensions.*

We consider the cubic focusing NLS in the exterior of strictly convex obstacle in three dimensions. We prove that even the ground state is not achieved in the obstacle case, the threshold for the global existence and scattering is the same as for the whole space problem. Specifically we prove that under the condition that $E(u)M(u) < E(Q)M(Q)$ and $\|\nabla u_0\|_2 \|u_0\|_2 < \|\nabla Q\|_2 \|Q\|_2$, the corresponding solution to the initial boundary value problem with Dirichlet boundary condition exists globally and scatters. Here, $Q(x)$ is the ground state of focusing cubic NLS in whole space case. (Received September 16, 2013)

1096-35-1874 **Svitlana Mayboroda*** (svitlana@umn.edu), School of Mathematics, 206 Church st SE, Minneapolis, MN 55455, and **Marcel Filoche** (marcel.filoche@polytechnique.edu). *Localization of eigenfunctions.*

The property of the localization of the eigenfunctions in rough domains or rough materials permeates acoustics, quantum physics, elasticity, to name just a few. Localization on fractal domains was used for noise abatement walls which up to date hold world efficiency record. Anderson localization of quantum states of electrons has become one of the most studied subjects in quantum physics, harmonic analysis, and probability alike. Yet, no deterministic results could predict specific spatial location of the localized waves.

In this talk I will present recent results which demonstrate a universal mechanism governing localization of the eigenfunctions of an elliptic operator. We prove that for any operator on any domain one can reveal a "landscape" which splits the domain into disjoint subregions. Starting from this landscape, we recover location, shapes, and frequencies of the localized eigenfunctions of low energy, and describe the effects of delocalization taking place as energy increases. (Received September 16, 2013)

1096-35-1912 **Benoit Pausader*** (pausader@math.princeton.edu). *The nonlinear Schrodinger equation on quotients of the Euclidean space.*

We study the asymptotic behavior of the nonlinear Schrodinger equation on semi-periodic manifolds $\mathbb{R}^n \times \mathbb{T}^d$. This is a joint work with Z. Hani, N. Tzvetkov and N. Visciglia. (Received September 16, 2013)

1096-35-1914 **Dhanapati Adhikari*** (dadhikari@marywood.edu), 2300 Adams Avenue, Scranton, PA 18509, and **Chongsheng Cao**, **Jiahong Wu** and **Xiaojing Xu**. *Small global solutions to the damped two-dimensional Boussinesq equations.*

The two-dimensional (2D) incompressible Euler equations have been thoroughly investigated and the resolution of the global (in time) existence and uniqueness issue is currently in a satisfactory status. In contrast, the global regularity problem concerning the 2D inviscid Boussinesq equations remains widely open. In an attempt to understand this problem, we examine the damped 2D Boussinesq equations and study how damping affects the regularity of solutions. Since the damping effect is insufficient in overcoming the difficulty due to the "vortex stretching", we seek unique global small solutions and the efforts have been mainly devoted to minimizing the smallness assumption. By positioning the solutions in a suitable functional setting (more precisely the homogeneous Besov space $\mathring{B}^1_{\infty,1}$), we are able to obtain a unique global solution under a minimal smallness assumption. (Received September 16, 2013)

1096-35-1915 **Zhiwu Lin*** (zlin@math.gatech.edu), **Chongchun Zeng** and **Zhengping Wang**. *Stability of traveling waves of Gross-Pitaevskii equation.*

The Gross-Pitaevskii equations are widely used in modeling superfluids and Bose-Einstein condensates. The GP equation has traveling waves solutions which have non-vanishing limit at infinity, first discovered by physicists (Jones,Roberts et al., 1980s). The existence of such traveling waves has been studied a lot in recent years by Betheul, Saut, Maris and many others. However, the stability and dynamical behaviors near such traveling waves are not well understood. With Zhengping Wang and Chongchun Zeng, we proved a nonlinear stability criterion for 3D traveling waves as conjectured in the physical literature, under a non-degeneracy assumption. Moreover, we prove that 2D traveling waves are always transversely unstable. The stable and unstable manifolds are constructed near unstable traveling waves. The stability criterion was also obtained for traveling waves of general nonlinear Schrödinger equation with nonzero condition at infinity. (Received September 16, 2013)

1096-35-1923 **C. Y. Chan** (chan@louisiana.edu) and **P. Tragoonsirisak*** (tragoonsirisakp@fvsu.edu). *Blow-up phenomena due to a concentrated nonlinear source in an infinite strip.*

This article studies a semilinear parabolic first initial-boundary value problem with a concentrated nonlinear source in an infinite strip. Criteria for global existence of the solution u and for u to blow up in a finite time are given. (Received September 16, 2013)

1096-35-1926 **Zhiwu Lin*** (zlin@math.gatech.edu). *Invariant Manifolds for Euler Equations and related equations.*

Consider a linearly unstable steady state of 2D or 3D Euler equations. With Chongchun Zeng, we prove the existence of stable and unstable manifolds near such unstable flows under a spectral gap condition. In particular, the gap condition can be verified for any linearly unstable 2D and 3D shear. The existence of invariant manifolds reveals the local dynamical structures near an unstable flow. The main difficulties of proving existence of invariant manifolds for Euler equations are due to the loss of derivatives in the nonlinear terms and the non-smoothing property of the linearized Euler operator. We developed a mixed Eulerian and Lagrangian approach to handle these difficulties. This approach had been extended to construct invariant manifolds for other problems, including the density dependent Euler equations (with Zeng and Shvydkoy) and Vlasov-Poisson equation for collisionless plasmas (with zeng). (Received September 16, 2013)

1096-35-1969 **Peter Constantin*** (const@math.princeton.edu), Fine Hall, Washington Road, Princeton, NJ 08540. *Local formulas for the hydrodynamic pressure and applications.* Preliminary report.

We will present local formulas for the pressure of incompressible hydrodynamics and some applications. (Received September 16, 2013)

1096-35-1975 **Peter Constantin*** (const@math.princeton.edu), Fine Hall, Washington Road, Princeton, NJ 08544. *Pressure formulas and regularity criteria.*

We will present some criteria of regularity for incompressible fluid equations based on local representations of the pressure. (Received September 16, 2013)

1096-35-1995 **Ryan Hynd*** (rhynd@math.upenn.edu), Philadelphia, PA 19104. *Introduction to the Euler-Poisson system.*

Understanding the dynamics of a system of interacting particles subject to pairwise conservative forces has remained a challenge in physics for many years. When the system has a large number of particles, it is possible to make a mean field approximation and derive a model equation for the distribution of particles. This model equation is known as the "Euler-Poisson" system and it will be subject of this talk. (Received September 17, 2013)

1096-35-2008 **Paul Smith*** (smith@math.berkeley.edu) and **Baoping Liu**. *Wellposedness of the Chern-Simons-Schroedinger System.*

The Chern-Simons-Schroedinger model in two spatial dimensions is a covariant NLS-type problem and is L^2 critical. Joint work of the speaker with Baoping Liu and Daniel Tataru establishes local wellposedness in H^s, $s > 0$. More recent joint work of the speaker and Baoping Liu establishes stronger results under additional hypotheses. (Received September 17, 2013)

1096-35-2019 **Adrian Muntean*** (a.muntean@tue.nl), Department of Mathematics, Eindhoven University of Technology, 5600 MB Eindhoven, Netherlands. *Homogenization for a kinetic description of self-assembly of fibrous materials.*

We present a continuum PDE-ODE model for collagen self-assembly describing the interplay between the change in the polymer distribution and the evolution of monomers. We endow the model with periodc coeeficients, where the small parameter ϵ is interpreted as the ratio of lengths of monomers and fibrils. After applying a fixed-point homogenization argument and proving corrector estimates, we use information from the first-order corrections to explain the so-called "turbidity measurement".

This is joint work with B. van Lith and C. Storm (TU Eindhoven, NL). (Received September 17, 2013)

1096-35-2068 **Yu Deng*** (yudeng@math.princeton.edu). *Invariant measures for the Benjamin-Ono equation.*

We consider the periodic Benjamin-Ono equation. For each conserved quantity E_k with leading term $\|u\|_{\dot{H}^k}^2$, there is a formally invariant weighted Gaussian measure ν_k. We first prove the invariance of ν_k for $k = 1$ (i.e. the Gibbs measure), then discuss the case $k \in \{2, 3\}$. The latter is joint work with N. Tzvetkov and N. Visciglia. (Received September 17, 2013)

1096-35-2121 **Nguyen T Nguyen*** (nnguyen@math.uchicago.edu). *The Dirichlet and regularity problems in bounded Lipschitz domains for second order elliptic operators with bounded, real, but not necessarily symmetric, coefficients.* Preliminary report.

In this paper, we consider the L^2 boundary value problems for the divergence form second order elliptic equation $\mathcal{L}u = -\mathrm{div}(A\nabla u) = 0$ in $\Omega \subset \mathbb{R}^d_+$, a bounded Lipschitz domain, where the matrix A is assumed to be real but not necessarily symmetric. Suppose that A is close, in a Carleson measure sense, to an elliptic matrix that is continuous on the boundary $\partial\Omega$. In this setting, we show that the Dirichlet and regularity problems are solvable. We also provide similar positive answer in the system setting provided that the coefficients $A = (a_{ij}^{rs})$ satisfies the extra "symmetry" condition: $a_{ij}^{rs} + a_{ji}^{rs} = a_{ij}^{sr} + a_{ji}^{sr}$, and the Dirichlet problem is defined to include the square function estimate. (Received September 17, 2013)

1096-35-2127 **Anne Bronzi*** (annebronzi@gmail.com), **Milton Lopes Filho** and **Helena Nussenzveig Lopes**. *Global existence of a weak solution of the Euler equations with helical symmetry and L^p vorticity.*

In this talk we will prove global existence of a weak solution of the 3D incompressible Euler equations, in full space, for an initial velocity with helical symmetry, without swirl and whose initial vorticity is compactly supported in the axial plane and belongs to L^p, for some $p > 4/3$. This result is an extension of the existence part of the work of B. Ettinger and E. Titi, who studied well-posedness of the Euler equations with helical symmetry without swirl, with bounded initial vorticity, in a helical pipe. (Received September 17, 2013)

1096-35-2156 **Barbara Prinari*** (bprinari@uccs.edu), University of Colorado at Colorado Springs, 1420 Austin Bluffs Pkwy, Colorado Springs, CO 80918. *The inverse scattering transform for the focusing nonlinear Schrödinger equation with fully asymmetric non-zero boundary conditions.* Preliminary report.

We present the inverse scattering transform (IST) for the focusing nonlinear Schrödinger equation: $iq_t = q_{xx} + 2|q|^2 q$ with non-zero boundary values $q_\pm(t)$ as $x \to \pm\infty$, in the fully asymmetric case $q_+ \neq q_-$. The direct problem is shown to be well-posed for potentials $q(x,t)$ such that $q(x,t) - q_\pm(t) \in L^{1,1}(\mathbb{R}^\pm)$ with respect to x for

all $t \geq 0$, for which analyticity properties of eigenfunctions and scattering data can be established. The inverse scattering problem is formulated both via (left and right) Marchenko integral equations, and as a Riemann-Hilbert problem on a single sheet of the scattering variables $\lambda_{\pm} = \sqrt{k^2 - |q_{\pm}|^2}$, k being the usual complex scattering parameter in the IST.
This talk is based on a joint work in progress with Francesco Demontis and Cornelis van der Mee (Universitá di Cagliari, Italy), and Federica Vitale (Universitá del Salento e Sezione INFN di Lecce, Italy). (Received September 17, 2013)

1096-35-2166 **Ratnasingham Shivaji*** (shivaji@uncg.edu), Department of Mathematics and Statistics, University of North Carolina at Greensboro, Greensboro, NC 27412. .

We consider the problem

$$-\Delta_p u = \frac{au^{p-1} - bu^{\gamma-1} - c}{u^\alpha}, \quad x \in \Omega$$
$$u = 0, \quad x \in \partial\Omega$$

where $\Delta_p u = \text{div}\left(|\nabla u|^{p-2}\nabla u\right)$, $p > 1$, Ω is a bounded domain with smooth boundary in $\mathbb{R}^n$, $a > 0$, $b > 0$, $c \geq 0$, $\gamma > p$ and $\alpha \in (0, 1)$. Given a, b, γ, and α, we establish the existence of a positive solution for small values of c. (Received September 17, 2013)

1096-35-2194 **Mythily Ramaswamy*** (mythily@math.tifrbng.res.in), P.B No. 6503, G.K.V.K Post, Bangalore, Karnataka 560065, India, and **Jean-Pierre Raymond** and **Debayan Maity**. *Stabilizability of Differential Equations.*

For a system of linear ordinary differential equations

$$Y'(x) = AY(x); Y(0) = Y_0$$

the stability is determined by the eigenvalues of the matrix A. For a controlled system of ODE

$$Y'(x) = AY(x) + Bu$$

the concept of feedback control in the form $u = Ku$ for a suitable matrix K, for which all the eigenvalues of $A + BK$ have negative real part, will be recalled and the method to calculate such feedback control will be indicated. Similar feedback controls for PDE systems will be discussed in the context of Compressible Navier-Stokes system. (Received September 17, 2013)

1096-35-2292 **Brian Pigott** and **Sarah Raynor*** (raynorsg@wfu.edu). *A New Approach to Soliton Stability for the KdV Equation.*

In this work, we consider the KdV equation in the exponentially weighted spaces of Pego and Weinstein. We prove local well-posedness of the perturbation (weighted and unweighted) in the Bourgain $X^{1,b}$ space, allowing us to recreate the Pego-Weinstein result via iteration. By combining this result with the I-method, we expect ultimately to obtain soliton stability for KdV with initial data too rough to be in H^1. (Received September 17, 2013)

1096-35-2293 **Gurgen Hayrapetyan*** (ghayrap@andrew.cmu.edu) and **Keith Promislow**. *Spectra of Functionalized Operators Arising from Hypersurfaces.*

Functionalized energies, such as the Functionalized Cahn-Hilliard, model phase separation in amphiphilic systems, in which interface production is limited by competition for surfactant phase, which wets the interface. This is in contrast to classical phase-separating energies, such as the Cahn-Hilliard, in which interfacial area is energetically penalized. In binary amphiphilic mixtures, interfaces are characterized not by single-layers, which separate domains of phase A from those of phase B via a heteroclinic connection, but by bilayers, which divide the domain of the dominant phase, A, via thin layers of phase B formed by homoclinic connections. Evaluating the second variation of the Functionalized energy at a bilayer interface yields a functionalized operator. We characterize the center-unstable spectra of functionalized operators and obtain resolvent estimates to the operators associated with gradient flows of the Functionalized energies. This is an essential step to a rigorous reduction to a sharp-interface limit. (Received September 17, 2013)

1096-35-2295 **Kazuo Yamazaki*** (kyamazaki@math.okstate.edu), 401 Mathematical Sciences Building, Department of Mathematics, Oklahoma State University, Stillwater, OK 74078. *On the global well-posedness of N-dimensional generalized MHD system in anisotropic spaces.*

We follow the approach of Iftimie (1999, Rev. Mat. Iberoamericana, 15, 1-36) to study the N-dimensional generalized magnetohydrodynamics (MHD) system with fractional Laplacians as dissipative and diffusive terms in various anisotropic spaces. In particular we obtain small initial data results with anisotropic Sobolev space type norms for which depending on the power of the fractional Laplacians, we may decrease the regularity index in many directions to zero or even negative, in the expense of increasing the rest. Similar results in anisotropic Besov type spaces are also obtained. We also discuss recent developments on the stochastic Navier-Stokes equations and MHD system. (Received September 17, 2013)

1096-35-2313 **Gary DeClerk***, Hendrix College, 1600 Washington Avenue, Conway, AR 72032, and **Jeremiah Bill** and **Quan Nguyen**. *Geometric Mean Value Properties.* Preliminary report.

We look at variations on the classical mean value property of harmonic functions. We investigate functions for which the value at the center of a disk is equal to the geometric mean of the function on the boundary of the disk. We show that a function has this property if and only if its log is harmonic. We then take advantage of this property to approximate solutions to problems through an iterative numerical process. We close with a generalized version of this property using L^p averages along the boundary of disks. (Received September 17, 2013)

1096-35-2421 **Gino Biondini*** (biondini@buffalo.edu), Buffalo, NY 14260. *Nonlinear Schrodinger systems with non-zero boundary conditions.*

Despite having been intensely investigated over the last forty years, nonlinear Schrodinger (NLS) systems still offer some surprises. This talk will discuss recent results on the initial-value problem (IVP) for both focusing and defocusing, scalar and vector, NLS systems with non-zero boundary conditions at infinity. The solution of the IVP for these systems via the inverse scattering transform will be outlined, various explicit soliton solutions will be presented, and spectral problems for some specific classes of initial conditions will be discussed. (Received September 17, 2013)

1096-35-2439 **D S Stutson*** (dstutson@xula.edu) and **A S Vatsala**. *Super Hyperbolic Linear Partial Fractional Differential Equations in One Dimensional Space.*

A representation form for the solution to the Super Hyperbolic Fractional Partial Differential Equation in one dimensional space is obtained by using the eigenfunction expansion method. The equation is called super Hyperbolic if the time derivative is of order q where $2 < q < 3$. $q = 2$ results in the second order linear hyperbolic equation in one dimensional space. (Received September 17, 2013)

1096-35-2483 **A. Bass Bagayogo*** (abagayogo@ustboniface.ca), 200 de la cathedrale, Winnipeg, Manitoba R2H 2T7, Canada. *Symbolic Solutions For Radial-Symmetric and Axial-Symmetric Groundwater Flow in Term of Special Functions.* Preliminary report.

Groundwater makes up nearly 30% of the entire world's freshwater but the mathematical models for the better understanding of the system are difficult to validate due to the disordered nature of the porous media and the complex geometry of the channels of flow. In this talk I will first establish the general 3D groundwater equations as expressed in Eqs. (1)

$$\frac{\partial}{\partial x}\left(K_x\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_y\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_z\frac{\partial h}{\partial z}\right)=S_s\frac{\partial h}{\partial t} \tag{1}$$

Where:

h = the hydraulic head

K = the hydraulic conductivity

$S_s = \rho g(\alpha + nB)$, the specific storage, with:

α = the compressibility of aquifer

B = the compressibility of the water

ρg = the specific weight of the water

By transforming the Eqs. (1) in different coordinate systems and by using the modern Computer Algebra System, I will show that dependant of the initial and boundary conditions, the solutions of Eqs. (1) could be expressed in term of special functions like Bessel, Error, Polder, Airy, Henkel and others related special functions. These functions are of considerable importance for solutions of radial-symmetric and axial-symmetric flow. (Received September 17, 2013)

1096-35-2494 **Sorathan Chaturapruek*** (tummykung@gmail.com), Harvey Mudd College (Box #100), 340 E. Foothill Blvd., Claremont, CA 91711, and **Jonah Breslau**, **Daniel Yazdi**, **Theodore Kolokolnikov** and **Scott G. McCalla**. *Crime Modeling with Lévy Flights.*

We extend the Short *et al.* model of crime to incorporate biased Lévy Flights for the criminal's motion, with step-sizes distributed according to a power-law distribution. Such motion is considered to be more realistic than the biased diffusion that was originally proposed. This generalization leads to fractional Laplacians. We then investigate the effect of introducing the Lévy Flights on the formation of hot-spots using linear stability and full numerics. Joint works with Jonah Breslau, Daniel Yazdi, Theodore Kolokolnikov, and Scott McCalla. (Received September 17, 2013)

1096-35-2498 **Jesus R Oliver*** (jroliver@math.ucsd.edu), San Diego, CA 92092. *A Vector Field Method for Non-Trapping Radiating Space-Times.*

In this work we study the global pointwise decay properties of solutions to the inhomogeneous linear wave equation $\square_g \phi = F(t,x)$ on time-dependent, non-trapping, radiating space-times. Assuming a local energy decay estimate we prove that sufficiently regular solutions to this equation satisfy a conformal energy estimate and higher order conformal energy estimate with vector fields. As an application we also establish a global pointwise decay estimate of the form $|\phi(t,x)| \lesssim \frac{1}{\langle t+r\rangle \langle u\rangle^{\frac{1}{2}}}$ for sufficiently regular solutions to the linear wave equation. (Received September 17, 2013)

1096-35-2555 **Michele Coti Zelati*** (micotize@indiana.edu), **Filippo Dell'Oro** and **Vittorino Pata**. *Energy decay of type III linear thermoelastic plates with memory.*

We analyze the decay properties of the solution semigroups generated by an abstract version of the linear systems

$$\begin{cases} u_{tt} + \Delta^2 u + \Delta\alpha_t = 0 \\ \alpha_{tt} - \Delta\alpha - \Delta\alpha_t - \Delta u_t = 0 \end{cases}$$

and

$$\begin{cases} u_{tt} + \Delta^2 u + \Delta\alpha_t = 0 \\ \alpha_{tt} - \Delta\alpha - \int_0^\infty \mu(s)\Delta[\alpha(t) - \alpha(t-s)]\, ds - \Delta u_t = 0 \end{cases}$$

ruling the evolution of linear thermoelastic plates within the theory of heat conduction of type III. (Received September 17, 2013)

1096-35-2562 **N. Mavinga*** (mavinga@swarthmore.edu), Department of Mathematics and Statistics, Swarthmore College, 500 College Avenue, Swarthmore, PA 19081, and **M. N. Nkashama**. *Bifurcation and multiplicity for elliptic equations with nonlinear boundary conditions.*

We present multiplicity results for solutions of second order elliptic partial differential equations with nonlinear boundary conditions. We establish a priori estimates and use topological degree and bifurcation from infinity arguments. (Received September 17, 2013)

1096-35-2574 **M. N. Nkashama*** (nkashama@math.uab.edu), Department of Mathematics, University of Alabama at Birmingham, Birmingham, AL 35294-1170. *Asymptotic Constancy for Solutions of Neutral Functional Partial Differential Equations.*

We will present convergence results for initial-boundary value problems for neutral functional partial differential equations for which each constant function is an equilibrium solution. Applications to lossless transmission line networks will also be discussed. (Received September 17, 2013)

1096-35-2580 **Guoping Zhang*** (guoping.zhang@morgan.edu), 1700 E Cold Spring Ln, Baltimore, MD 21251. *Traveling wave solutions of Camassa-Holm equation.* Preliminary report.

In this talk I will talk about all bounded continuous traveling wave solutions of Camassa-Holm equation by using our direct construction method. (Received September 17, 2013)

1096-35-2602 **Fan Yang*** (jackie@math.udel.edu), 501 Ewing Hall, Department of Mathematical Sciences, University of Delaware, Newark, DE 19716, and **Peter Monk** (monk@math.udel.edu), 513 Ewing Hall, Department of Mathematical Sciences, University of Delaware, Newark, DE 19716. *The Interior Transmission Problem for Regions on Conducting Surface.*

We consider the interior transmission problem corresponding to inverse scattering for a bounded isotropic dielectric medium lying on an infinite conducting surface. In particular, we investigate the 2-D scalar case of this problem where, in the corresponding scattering problem, the dielectric medium is illuminated by time harmonic Transverse-Electric (TE) or Transverse-Magnetic (TM) polarized electromagnetic waves respectively. In both cases we establish the Fredholm property for this problem and show that transmission eigenvalues exist and form a discrete set. We also derive Faber-Krahn type inequalities for the transmission eigenvalues. Numerical results for the TE and TM cases are given showing that real transmission eigenvalues can be found from near field data, although in some cases the accuracy requirements on the data is very stringent. (Received September 17, 2013)

1096-35-2638 **Mihaela Ignatova**, **Igor Kukavica*** (kukavica@usc.edu), **Irena Lasiecka** and **Amjad Tuffaha**. *On the well-posedness of 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. We provide a priori estimates for local existence and uniqueness of solutions and establish global existence for small initial data. (Received September 17, 2013)

1096-35-2645 **Andras Balogh*** (abalogh@utpa.edu), Department of Mathematics, The University of Texas-Pan American, 1201 W. University Drive, Edinburg, TX 78539. *Well-Posedness of a Boundary Controlled Generalized Burgers-Korteweg-de Vries Equation.*
We consider a Generalized Burgers-Korteweg-de Vries Equation on a finite interval with nonlinear boundary conditions representing stabilizing boundary feedback control laws. The theory of monotone operators is used with locally Lipschitz perturbations in order to show the existence of solutions. (Received September 17, 2013)

1096-35-2701 **Netra P Khanal*** (nkhanal@ut.edu), 7852 Tuscany Woods Dr, Tampa, FL 33647. *Complex Valued Partial Differential Equations.*
Complex valued partial differential equations will be introduced in this talk. The finite time blow up results for complex KdV equation, and complex Burgers equation will be discussed in detail. (Received September 18, 2013)

1096-35-2728 **Aynur Bulut*** (abulut@ias.edu), Department of Mathematics, University of Michigan, Ann Arbor, MI. *Gibbs measure evolution and probabilistic global well-posedness for radial nonlinear Schrödinger and wave equations on the unit ball.*
We discuss recent works, joint with Jean Bourgain, in which we establish new global well-posedness results along Gibbs measure evolutions for the radial nonlinear wave and Schrödinger equations posed on the unit ball in R^N. We consider initial data consisting of Gaussian random processes lying in the support of the associated Gibbs measures, and results are obtained almost surely with respect to these probability measures. Our techniques are based on an analysis of convergence properties of solutions to sequences of finite-dimensional projections of the equations. Key tools include a class of probabilistic a priori bounds, estimates of fine frequency interactions for solutions of the projected equations, and use of invariance properties of the Gibbs measure which allow to extend our bounds to arbitrary long times. (Received September 18, 2013)

1096-35-2759 **Reza Malek-Madani*** (rmm@usna.edu), 121 Blake Rd., Annapolis, MD 21402, and **Kevin McIlhany** and **Kayo Ide**. *A Lagrangian and Eulerian Analysis of a Geophysical Fluid Flow arising in the Chesapeake Bay.*
We present results for a velocity vector field obtained from solving the governing partial differential equations of motion in the domain defined by the Chesapeake Bay, and augmented with boundary conditions and wind forcing terms supplied from field data. The underlying time-dependent dynamical system, which is discrete in time and space, is then studied with the purpose of identifying its invariant manifold structure. Several metrics, Lagrangian as well as Eulerian, will be computed with the goal of understanding special features of the fluid flow in this three-dimensional estuary. Special attention is given to regions in the bay where the geometry is complex, as well as to the mouth of the bay where understanding transport and mixing there remains a critical area of research. A significant part of this effort is dedicated to comparing various metrics and their skills in predicting invariant structures. (Received September 18, 2013)

37 ► Dynamical systems and ergodic theory

1096-37-108 **Robyn Ferg*** (fergr@stolaf.edu), Department of Mathematics, St. Olaf College, Northfield, MN 55057, and **Anna Szczekutowicz** (aszczekutowicz@yahoo.com), Hill Center for the Mathematical Sciences, Rutgers University, Piscataway, NJ 08854-8019. *Basins of attraction of ECM solutions of the Lang-Kobayashi system.*
The Lang-Kobayashi system of delay differential equations describes the behavior of the complex electric field E and inversion N of external cavity semiconductor lasers. This system has a family of periodic solutions known as external cavity modes (ECMs). As the feedback value is increased, these ECM solutions appear through saddle-node bifurcations, then lose stability through a Hopf bifurcation. Using analytical and numerical techniques, we explore a parameter region where 3 simultaneous stable ECM solutions exist, and we describe how the basins of these attractors change as the bifurcation parameter (the feedback value) is increased. We give an introduction to

the corresponding problem and the resulting challenges in the case of mutually delay coupled lasers. (Received July 30, 2013)

1096-37-128 **Josh Jacobson*** (joshhjacobson@gmail.com), Department of Mathematics, St. Olaf College, Northfield, MN 55057, and **Peter Valdez** (pvald@hunter.cuny.edu), Department of Mathematics and Statistics, Hunter College, New York, NY 10065. *Numerical Analysis of Cardiac Electrophysiology Models.*

Cardiac electrophysiology is the study of electricity flow through the heart. The computational models used in the field typically describe cells using systems of nonlinear ordinary differential equations (ODEs); when cells are coupled together to form tissue, the medium becomes a nonlinear reaction-diffusion system that cannot be solved analytically. As a result, numerical techniques must be applied to find solutions. In practice, many implementations of these models use forward Euler as the integration scheme. Using three cardiac models of varying complexity from two to 29 coupled ODEs, we apply forward Euler and several other first- and second-order numerical integration schemes. We compare the methods to each other using different metrics, including run time, electrical wave structure, and the accuracy of electrical properties such as action potential duration and conduction velocity. Our analysis gives a better understanding of the costs and benefits of using various integration schemes and hopefully will enable researchers to achieve desired results in a shorter time. (Received August 01, 2013)

1096-37-145 **Darren Creutz*** (darren.creutz@vanderbilt.edu). *Stabilizers of Ergodic Actions of Lattices.*

I will present an overview of my recent work, both joint with J. Peterson and solo, classifying the possible actions of lattices in semisimple groups, and more generally, products of groups with the Howe-Moore property. The main result is that, provided at least one simple factor in the ambient group has property (T) (is of higher-rank), every ergodic probability-preserving action of such a lattice on a nonatomic space is essentially free. I will also explain more recent work, joint with J. Peterson, on the rigidity for characters on such lattices, the noncommutative analogue of the statement on actions. (Received August 08, 2013)

1096-37-148 **Chris Rackauckas** (me@chrisrackauckas.com) and **James A. Walsh*** (jawalsh@oberlin.edu). *A dynamics approach to an alternative to the Snowball Earth climate state.*

Evidence exists indicating glaciers flowed into the ocean near the equator during the Neoproterozoic Era. Some conjecture the Earth was in a snowball state, its oceans completely covered with ice. Others posit ice sheets descended to tropical latitudes without advancing to the equator. We investigate the latter hypothesis via an approximation to a well-known infinite dimensional, coupled temperature–ice line model. The approximation results in a system of seven first order ODEs, for which a globally attracting three-dimensional manifold Γ exists. Using geometric singular perturbation theory, we prove the existence of an attracting one-dimensional invariant manifold within Γ. We use this result to show there is a stable equilibrium solution for which the ice line rests at roughly 10° N for suitably chosen model parameters. (Received August 09, 2013)

1096-37-209 **Su Gao** and **Aaron Hill*** (aaron.hill@unt.edu). *The isomorphism problem for rank-1 systems.* Preliminary report.

We'll discuss the (measure-theoretic) isomorphism problem for rank-1 transformations. Foreman, Rudolph, and Weiss showed in 2011 that the isomorphism relation on rank-1 transformations is Borel, but no explicit Borel description of the isomorphism relation is currently known. We'll describe ways of producing measure-theoretic isomorphisms between rank-1 transformations and connections to the isomorphism problem (when are two rank-1 transformations isomorphic?), the inverse problem (when is a rank-1 transformation isomorphic to its inverse?) and the centralizer problem (what isomorphisms exist between a rank-1 transformation and itself?). (Received August 19, 2013)

1096-37-210 **Joseph Rosenblatt*** (rosnbltt@illinois.edu), Department of Mathematics, 273 Altgeld Hall, 1409 W. Green St., Urbana, IL 61801. *Coboundaries and ergodic sums.* Preliminary report.

The behavior of the norms of ergodic sums can be used to characterize coboundaries. But the behavior of the norms of ergodic sums can be fairly chaotic. Moreover, for a given function, which classes of transformations have that function as a coboundary is a complex issue. These types of things will be considered in some detail for general ergodic transformations of a probability space. (Received August 19, 2013)

1096-37-268 **Aisha Najera Chesler***, aisha.najera@cgu.edu, and **Ami E Radunskaya**. *Heart Rate and EEG modeling during labor: predicting fetal distress.* Preliminary report.

During labor, fetal well-being is typically monitored by measuring fetal heart rate (FHR). However, continuous FHR monitoring has been associated with increased rates of surgical interventions (e.g., caesareans) and is not a reliable predictor for severe academia (low pH in the blood) which can develop from the lack of oxygen reaching the tissues. This condition is commonly caused by umbilical cord occlusions and can cause permanent brain injuries to the fetus. More reliable monitoring modalities and methods of signal analysis, which can provide early detection of developing acidemia, are needed. To address this, I present a mathematical model which explores the monitoring of two signals, FHR and electroencephalogram (EEG), as a way to predict fetal distress. (Received August 25, 2013)

1096-37-292 **Michel L. Lapidus** (lapidus@math.ucr.edu), 900 University Ave, Surge Building, Department of Mathematics, Riverside, CA 92521, **Robyn L. Miller** (rlm35@cornell.edu), Department of Mathematics, 310 Malott Hall, Cornell University, Ithaca, NY 14853, and **Robert G. Niemeyer*** (niemeyer@math.unm.edu), Science and Math Learning Center 332, 311 Terrace NE, MSC01 1115, Albuquerque, NM 87131. *Billiard dynamics on the T-fractal billiard table.*

Substantial progress has been made in determining periodic orbits of the T-fractal billiard table. We detail some of the recent results concerning periodic orbits, determined in collaboration with M. L. Lapidus and R. L. Miller. Less has been done to determine what may constitute a dense orbit of the T-fractal billiard. We provide substantial experimental and theoretical evidence in support of the existence of an orbit that is dense in the T-fractal billiard table but is not a space-filling curve. We briefly touch on a long-term goal of determining a topological dichotomy for the flow on the T-fractal billiard table, namely that, in a fixed direction, the flow is either closed or minimal. (Received August 27, 2013)

1096-37-317 **Kathryn A. Lindsey*** (klindsey@math.cornell.edu). *Shapes of Polynomial Julia Sets.*

Would you like to find a polynomial whose Julia set looks like a car? a triangle? a cat? This talk will tell you how to construct such a polynomial. I proved that any Jordan curve in the plane can be approximated arbitrarily well in the Hausdorff topology by the Julia sets of polynomials. Finite unions of disjoint Jordan curves can be approximated by the basins of attraction of rational maps. I will discuss these results and show some pictures of neat Julia sets. (Received August 28, 2013)

1096-37-411 **Turgay Bayraktar*** (tbayrakt@indiana.edu), 831 E Third St, Bloomington, IN 47405. *Random iteration in CP^k.*

We consider some ergodic properties of random holomorphic endomorphisms of complex projective space. By a “random holomorphic endomorphism” we mean a random variable which takes values with probability one in the set of holomorphic endomorphisms of fixed algebraic degree. The focus will be on dynamical properties of compositions of identically distributed independent random holomorphic maps. For a sequence of holomorphic endomorphisms, we construct a positive closed bidegree (p,p) current which describes asymptotic distribution of pre-images of a generic subvariety of codimension p. Under a natural assumption on the distribution of the sequence these currents have Hölder continuous quasi-potentials. If, in addition, the distribution is compactly supported in the set of holomorphic endomorphisms then we obtain exponential decay of correlations and this in turn implies Central Limit Theorem for Hölder continuous and d.s.h. observables. (Received September 09, 2013)

1096-37-415 **David M. McClendon***, Mathematics Department, 820 Campus Drive, ASC 2021, Big Rapids, MI 49307, and **Aimee S.A. Johnson**, 50 College Avenue, Swarthmore, PA 19081. *Speedup equivalence of ergodic $\mathbb{Z}^d-$actions.*

In 1985 Arnoux, Ornstein and Weiss proved that given any two ergodic measure-preserving transformations, there is a speedup of one which is isomorphic to the other. Recently, Babichev, Burton and Fieldsteel gave a relative version of this result and used their result to give a complete classification of finite extensions of ergodic transformations up to “speedup equivalence”. In this talk, we define an appropriate notion of “speedup” for measure-preserving actions of $\mathbb{Z}^d$ and discuss results analogous to those described above for actions of $\mathbb{Z}^d$. (Received September 03, 2013)

1096-37-418 **Jacqueline Anderson*** (jacqueline.anderson@bridgew.edu). *p-adic Mandelbrot sets and their boundaries.*

Let $f(z) = z^d + a_{d-1}z^{d-1} + \cdots + a_1 z \in \mathbb{C}_p[z]$ be a polynomial of degree d. We say f is *post-critically bounded*, or PCB, if all of its critical points have bounded orbits under iteration of f. Let $\mathcal{M}_{d,p}$ be the set of such PCB polynomials. This is the p-adic Mandelbrot set of degree d. It is known that if $p \geq d$, then $f \in \mathcal{M}_{d,p}$ if and only if all critical points of f have p-adic absolute value less than or equal to 1. When $p < d$, however, these sets are much more interesting. We will discuss this case and how the boundaries of these sets exhibit properties similar to that of the complex Mandelbrot set. (Received September 03, 2013)

1096-37-427 **E. Arthur Robinson, Jr.***, Department of Mathematics, George Washington University, Washington, DC 20052. *Parry's topological transitivity and f-expansions.*

In his 1964 paper on f-expansions, Parry studied piecewise-continuous, piecewise-monotonic interval maps F, and introduced a notion of topological transitivity different from any of the modern definitions. This notion, which we call *Parry topological transitivity*, is that the *backward orbit* $O^-(x) = \{y : x = F^n y \text{ for some } n \geq 0\}$ of some x is dense. We show that topological transitivity (i.e., a dense *forward* orbit) implies Parry topological transitivity, but that the converse is false. We discuss Parry's application of these ideas to the theory of f-expansions, and provide a modern variation on these ideas. (Received September 03, 2013)

1096-37-435 **Karl Petersen*** (petersen@math.unc.edu), Department of Mathematics, University of North Carolina, Chapel Hill, NC 27599, and **Benjamin Wilson**, Departrment of Mathematics, University of North Carolina, Chapel Hill, NC 27599. *Measuring complexity and interconnectivity in dynamical systems.* Preliminary report.

Edelman, Sporns, and Tononi proposed a variation on entropy that they called "intricacy" as a measure of complexity or interconnectivity of neural networks. Buzzi and Zambotti studied it for families of random variables. We define a version for dynamical systems and examine some of its properties, including comparison with the usual measure-theoretic and topological entropies. (Received September 11, 2013)

1096-37-460 **Matthieu Arfeux*** (marfeux@math.univ-toulouse.fr), Toulouse, France. *Trees of spheres and holomorphic dynamics.*

In the context of holomorphic dynamics in one complex variable, I will try to explain how one can use the Deligne-Mumford compactification of stables curves to compactify the set of dynamically marked rational maps of a fixed degree. (Received September 04, 2013)

1096-37-469 **Konstantin Medynets*** (medynets@usna.edu), Annapolis, MD 21402, and **Boris Solomyak**. *Second Order Ergodic Theorem for Substitution Tiling Systems.*

We consider infinite measure-preserving non-primitive self-similar tiling systems in Euclidean space $\mathbb{R}^d$. We establish the second-order ergodic theorem for such systems, with exponent equal to the Hausdorff dimension of a graph-directed self-similar set associated with the substitution rule. (Received September 04, 2013)

1096-37-495 **Jane M. Hawkins*** (jhawkins@nsf.gov), 1025 N, National Science Foundation, 4201 Wilson Blvd, Arlington, VA 22230. *Bernoulli properties and Julia sets for maps of the real projective plane.* Preliminary report.

We study maps of the real projective plane with the property that they are quotient maps of analytic, or rational, maps of the sphere; these are called dianalytic maps. We start by describing topological work done jointly with Sue Goodman showing how to construct these dianalytic maps via sphere maps. We next discuss measure theoretic properties of these maps with a view to identifying natural measures on the Julia sets, and give some results on one-sided Bernoulli and ergodic measures. We show for example, why the maps are not one-sided Bernoulli with respect to conformal measure and describe the unique measure of maximal entropy. We give examples where the Julia set is the projective plane and discuss ergodic properties of these maps. (Received September 04, 2013)

1096-37-515 **J. D. Mireles James*** (jmireles@math.rutgers.edu) and **Haripriya Chakraborty**. *Approximation of Julia sets with computer assisted validation for complex analytic dynamical systems.*

I will discuss some computer assisted methods for mathematically rigorous approximation of Julia sets in complex analytic dynamical systems. The methods are based on solving the Schroder equation for the conjugacy map at a fixed point. This part of the problem is also treated by computer assisted arguments so that good bounds on the radius of convergence of the conjugating series are obtained. When the Schroder equation is solved at the attracting fixed point, then the boundary of the image of the conjugacy map provides an approximation of the Julia set. On the other hand computing the conjugacy map at a repelling fixed point allows for validated study of homoclinic connecting orbits via a certain "discrete free boundary value problem". The Julia set is approximated from below by taking the union of longer and longer homoclinic excursions. I will sketch the arguments and present some results for both a quadratic and an exponential family of maps. (Received September 05, 2013)

1096-37-521 **Eugen Andrei Ghenciu*** (ghenciue@uwstout.edu) and **Mario Roy** (mroy@glendon.yorku.ca). *"Bowen Formula in Generalized Iterated Constructions and Applications"*. Preliminary report.

There are a lot of connections between symbolic dynamics and dimension theory for generalized iterated constructions. A generalized iterated construction is the most general setting in which one can construct a limit sets extending the ideas from Graph Directed Markov Systems introduced by Mauldin and Urbanski. In this presentation we show that if there are finitely many iterates, the Bowen formula holds; meaning the Hausdorff dimension of the limit set is the zero of the associated topological pressure. Several examples and applications will be shown. Connections to symbolic dynamics and how to compute entropy will also be shown. (Received September 05, 2013)

1096-37-544 **Nai-Chia Chen*** (chen1945@umn.edu). *Periodic Brake Orbits in the Planar Isosceles Three-Body Problem.*

The isosceles three body problem is a special case of the three body problem where the configuration of the three bodies forms an isosceles triangle at every instant. The isosceles problem has two degree of freedom, and it has singularities due to the binary collisions of the two symmetric bodies and the triple collision. After applying McGehee's blow-technique and fixing the total energy, the flow of the differential equation is restricted to a three dimensional manifold, called the energy manifold.

Simó and Martinez extensively studied the energy manifold including its boundaries, namely the triple collision manifold and the infinity manifold. By using symbolic dynamics, they characterize orbits that pass near triple collision and near infinity. As a consequence, they obtain several families of periodic orbits, some of them are the so called periodic brake orbits.

A brake orbit is an orbit that starts with zero initial velocity. The purpose of this talk is to find periodic brake orbits in the isosceles three-body problem. By using various topological shooting arguments, we prove the existence of six types of periodic brake orbits. (Received September 05, 2013)

1096-37-629 **Aminur Rahman*** (ar276@njit.edu), 323 Martin Luther KIng Jr.Blvd, Newark, NJ 07102. *A Scheme for Modeling and Analyzing the Dynamics of Logical Circuits.*

It is shown how logical circuits can be modeled by discrete dynamical systems that preserve the qualitative behavior observed in physical realizations. While continuous dynamical systems provide quite accurate mechanistic models, they can become extremely computationally expensive to simulate. In contrast, simulating a discrete dynamical system is relatively inexpensive. A model for the RS flip-flop circuit, made with chaotic NOR gates, is found in an ad-hoc manner. This is shown to replicate the qualitative features of the physical realization. Next, a systematic - algorithmic - first principles based approach is developed in order for such dynamical models to more accurately reflect observed behavior and facilitate further investigation. Also, it is demonstrated how this fundamental algorithmic approach can, with similar ease, be used to obtain discrete dynamical models of other more complicated logical circuits. (Received September 16, 2013)

1096-37-749 **Bernat Espigule-Pons*** (bernatep@gmail.com). *Golden Trees and Their Relatives: A Mathematical Arboretum in 3D.*

In 2007, Tara Taylor presented the four self-contacting symmetric binary fractal trees that scale with the golden ratio. As she showed, theses trees possess remarkable symmetries in addition to the usual symmetries associated with symmetric binary fractal trees. Here, we reinforce the importance of her observations showing that there is an analogous critical behavior for symmetric ternary fractal trees. We introduce the five self-contacting ternary fractal trees that scale with the golden ratio, and we highlight some of their properties through the generalized equations for self-contacting symmetric n-ary fractal trees. In addition to these results, we exhibit the 3D-printed models of these five golden trees, and we quickly summarize the contents of the author's interactive website http://pille.iwr.uni-heidelberg.de/~fractaltree01/. The angles θ of the five self-contacting ternary symmetric golden trees are: $\cos^{-1}\left(\frac{1}{3}\right)$, $\tan^{-1}\left(\frac{4}{\sqrt{9\sqrt{38-14\sqrt{5}}+9\sqrt{5}-43}}\right)$, $2\tan^{-1}\left(\sqrt{\frac{1}{10}\left(5+3\sqrt{5}\right)}\right)$, $\cos^{-1}\left(-\frac{1}{3}\right)$ and $\cos^{-1}\left(-\frac{\sqrt{5}}{3}\right)$. (Received September 10, 2013)

1096-37-841 **Francis C. Motta*** (motta@math.colostate.edu), Department of Mathematics, 1874 Campus Delivery, Fort Collins, CO 80523-1874, and **Patrick D Shipman** (shipman@math.colostate.edu) and **Bethany Springer** (springer@math.colostate.edu). *Optimally Topologically Transitive Orbits of the Bernoulli Shift Map.*

We present a refinement of the notion of subset density for orbits of a discrete-time dynamical system on a metric space, which we think of as a measure of an orbit's *approach* to density. We consider first a motivating example: the family of rigid rotations $R_\theta : [0, 1) \to [0, 1)$ ($\theta \in (0, 1)$) defined by $R_\theta(x) = (x + \theta) \mod 1$. We then explore this notion for Bernoulli shifts on sequences over a finite alphabet, which leads to a connection to (infinite) de Bruijn sequences. (Received September 10, 2013)

1096-37-869 **Anushaya Mohapatra*** (am87@rice.edu) and **William Ott**. *Rank one dynamics near heteroclinic cycles.*

Identifying mechanisims that produce nonuniform hyperbolicity and proving that nonuniform hyperbolicity present in concrete models remain major challenges. We discuss the emergence of nonuniformly hyperbolic dynamics when certain flows with heteroclinic cycles are subjected to time-periodic forcing. In particular we show the emergence of SRB measures and the emergence of rank one chaos that is both sustained in time and physically observable. Heteroclinic cycles have been studied extensively in connection with dynamics on networks and systems possessing symmetries. Our results are independent of symmetry considerations. They apply in the presence of symmetries and in the absence of symmetries. (Received September 10, 2013)

1096-37-876 **Eric Bedford**, **Jeffery Diller** and **Kyounghee Kim*** (kim@math.fsu.edu). *Pseudo-automorphims with an invariant elliptic curve.*

Consider a birational map f given by the Cremona involution followed by an automorphism on P^k. Suppose f preserves a elliptic curve C, that is the closure of $f(C - Ind(f))$ is same as C. The group law on the elliptic curve gives a way to construct pseudo automorphisms on a rational k fold with a given orbit data. We will discuss about the construction and the properties of those maps. (Received September 10, 2013)

1096-37-916 **Jon Chaika*** (jonchaika@math.utah.edu), Jon Chaika, Dept Math, 155 S 1400 E, Room 233, Salt Lake City, IL 84112-0090, and **Jon Fickensher**. *Topological mixing for residual sets of interval exchange transformations.*

T is topologically mixing if for every pair of nonempty open sets U, V there exists N so that $T^n(U) \cap V \neq \emptyset$ for all $n > N$. The set of topologically mixing interval exchanges with a non-degenerate permutation on 4 or more letters is residual (contains a dense G-delta). This is joint work with Jon Fickenscher. (Received September 11, 2013)

1096-37-940 **Andrew Bridy*** (bridy@math.wisc.edu), Department of Mathematics, 480 Lincoln Drive, Madison, WI 53706. *The Artin-Mazur Zeta Function of a Rational Map in Positive Characteristic.*

The Artin-Mazur zeta function of a dynamical system encodes information about its periodic points. The zeta function of a rational map from $\mathbb{P}^1(\mathbb{C})$ to itself is always a rational function, but over a field of positive characteristic k, the form of the zeta function is not well understood. I show that a large class of self-maps of $\mathbb{P}^1(k)$ have zeta functions which are transcendental over the field of rational functions in one variable, and I give a heuristic argument that the zeta function of a generic rational map should be transcendental. (Received September 11, 2013)

1096-37-960 **Ronnie Pavlov*** (rpavlov@du.edu). *A characterization of topologically completely positive entropy for shifts of finite type.*

Blanchard defined a topological dynamical system to have *topologically completely positive entropy* (or TCPE) if every one of its nontrivial factors has positive topological entropy. (Here, 'nontrivial' means not consisting of a single fixed point) Though TCPE is not easy to characterize in general, we give a simple condition which is equivalent to TCPE for shifts of finite type.

For this, we define a relation called exchangeability: patterns $w, w' \in A^S$ are said to be *exchangeable* in a shift space X if there exist $x, x' \in X$ such that $x(S) = w$, $x'(S) = w'$, and x, x' differ on only finitely many sites. Interestingly, the exchangeability relation is not necessarily transitive, and it is the transitive closure which is related to TCPE. (Received September 11, 2013)

1096-37-1038 **Volodymyr Nekrashevych*** (nekrash@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77843. *Fredholm modules and spectral triples associated with hyperbolic groupoids.*

We will discuss natural Fredholm modules and spectral triples associated with pairs of mutually dual hyperbolic groupoids. Examples of hyperbolic groupoids include actions of Gromov hyperbolic groups on their boundaries, groupoids generated by expanding maps, groupoids associated with Smale spaces or Anosov flows, etc. (Received September 12, 2013)

1096-37-1078 **Daniel Cuzzocreo*** (dcuzz@bu.edu). *Parameter Space Structures for Singular Perturbations of Polynomials.*

The one-parameter families of maps of the form $z^n + \lambda/z^d$ form a convenient class of rational maps to analyze. As singular perturbations of $z \mapsto z^n$, their dynamics share important properties with those of polynomials. There is always a superattracting fixed point at infinity when $n \geq 2$, and for each fixed n and d there is a single free critical orbit, so we can study bifurcations by analyzing the behavior of the critical orbit in relation to external and internal rays. In this talk we discuss some of the structures that arise in the highly intricate parameter spaces for these families. (Received September 12, 2013)

1096-37-1127 **Eric Bedford*** (bedford@indiana.edu), Department of Mathematics, Stony Brook University, Stony Brook, NY 11794-3651. *Pseudo-automorphisms of point blowups of projective space.* Preliminary report.

Let $J(x_0, ..., x_k) = (1/x_0, ..., 1/x_k)$ denote the standard Cremona involution on complex projective space P^k, and let L denote a (linear) automorphism of P^k. We consider birational maps of the form $f = L \circ J$. We consider spaces X obtained by the (iterated) blow up of P^k at a (finite) number of points. We discuss the existence of linear maps L such that there is a space X for which the induced map f_X of X is a pseudo-automorphism. We also discuss the properties of such maps. (Received September 13, 2013)

1096-37-1133 **Gregory Varner*** (gvarner@jbu.edu), Siloam Springs, AR 72761. *Ergodicity for the Randomly Perturbed Navier-Stokes Equations.* Preliminary report.

We review recent results and present new results concerning the existence and uniqueness of a time-invariant measure for the two-dimensional Navier-Stokes equations on the sphere under a random kick-force and under white-noise forcing. In particular, the necessary conditions for the existence and uniqueness of the measure for the kick-force model as well as the physical relevance of the conditions are presented. Furthermore, a complete description of the support of the invariant measure is given for the white-noise and kick-force models considered, and the support of the kick-force equations is described under several physically relevant deterministic forcing. (Received September 13, 2013)

1096-37-1135 **David Ralston*** (ralstond@oldwestbury.edu), Department of Mathematics, SUNY College at Old Westbury, PO 210, Old Westbury, NY 11568. *Symbolic Dynamics and the Infinite Staircase.*

We will present a dyanmically-determined sequence of substitutions which encode a skew product $T_\alpha : \mathbb{S}^1 \times \mathbb{Z} \longrightarrow \mathbb{S}^1 \times \mathbb{Z}$ defined by

$$T_\alpha(x, n) = (x + \alpha \bmod 1, n + f(x)),$$

where $\alpha \notin \mathbb{Q}$ is given, and

$$f(x) = \begin{cases} 1 & (0 \leq x \leq 1/2) \\ -1 & (1/2 < x < 1). \end{cases}$$

This skew product is a cross-section of the geodesic flow on a particular translation surface of infinite measure and genus known as the *infinite staircase*.

Through explicit analysis of the substitutions as well as dynamic properties of the process which generates them, we may deduce properties about the geodesic flow, such as generic diffusion rates, certain α which give rise to explicit abnormal diffusion rates, and the existence of transient (non-recurrent) orbits for all α. (Received September 13, 2013)

1096-37-1179 **Joseph L Herning*** (joe.herning@gmail.com). *Bijective substitutions without topological subshift factors isomorphic to their maximal equicontinuous factors.*

This paper shows how to construct bijective substitutions which do not admit topological factors which are subshifts and also have infinite pure discrete spectrum. We first show how in the case of certain constant-length substitutions it is possible to achieve all non-trivial topological subshift factors, or sliding block codes, as substitutions. Then, we find among bijective substitutions examples for which the process can never yield a coincident substitution. (Received September 13, 2013)

1096-37-1230 **Chris Marx*** (cmarx@caltech.edu), Mathematics 253-37, Caltech, Pasadena, CA 91125. *Zero Lyapunov exponent for quasi-periodic Schrödinger operators.*

It was the fractal nature of the spectrum of the almost Mathieu operator, known as "Hofstadter's butterfly," which sparked the interest in quasi-periodic Schrödinger operators. They describe the influence of a magnetic field on the electrons in a crystal.

In physics the term "Cantor spectrum" is often used for appearance of singular continuous (SC) spectrum. Crucial in capturing this phenomenon is the Lyapunov exponent (LE) of the matrix cocycles associated with the Schrödinger equation. For analytic potentials and typical magnetic frequency, SC spectrum is known to occur only on the set of zero LE. As the same set also supports the absolutely continuous (AC) spectrum ("scattering states"), distinction of the two contributions is needed.

We discuss methods to localize the zero LE regime which explicitly distinguish between contributions from AC-("subcritical regime") and singular spectrum ("critical regime"). Applications include the self-dual, isotropic extended Harper's model where zero LE with purely SC spectrum could be proven, verifying a conjecture of Thouless. For a potential given by a trigonometric polynomial, a criterion for subcritical behavior is presented. The latter is based on upper bounds of the LE of the complexified Schrödinger cocycle. (Received September 13, 2013)

1096-37-1268 **Aijun Zhang***, Drexel University, Department of Mathematics, 3141 Chestnut St, Philadelphia, PA 19104. *TRAVELING WAVE SOLUTIONS WITH MIXED DISPERSAL FOR SPATIALLY PERIODIC FISHER-KPP EQUATIONS.*

Traveling wave solutions to a spatially periodic nonlocal/random mixed dispersal equation with KPP nonlinearity are studied. By constructions of super/sub solutions and comparison principle, we establish the existence of traveling wave solutions with all propagating speeds greater than or equal to the spreading speed in every direction. For speeds greater than the spreading speed, we further investigate their uniqueness and stability. (Received September 14, 2013)

1096-37-1269 **Nicholas Ormes*** (normes@du.edu) and **Ronnie Pavlov** (rpavlov@du.edu). *Extender sets and multidimensional subshifts.* Preliminary report.

In this talk, we consider a $\mathbb{Z}^d$ extension of the well-known fact that one-dimensional shifts with only finitely many follower sets are sofic. As in a paper of Kass and Madden, we adopt a natural $\mathbb{Z}^d$ analog of a follower set, called an extender set. The extender set of a finite word w in a $\mathbb{Z}^d$ symbolic system is the set of all configurations of symbols on the complement of w which, when concatenated with w, form a legal point of the system. We show that for any $d \geq 1$ and any $\mathbb{Z}^d$ subshift X, if there exists n so that the number of extender sets of words on a d-dimensional hypercube of side length n is less than or equal to n then X is sofic, i.e. a topological factor of a $\mathbb{Z}^d$ shift of finite type. There are easy examples of non-sofic systems for which this number of extender sets is $n+1$ for every n. (Received September 14, 2013)

1096-37-1308 **Joshua P Bowman*** (joshua.bowman@gmail.com), 8A Glenwood Ave, Northampton, MA 01060. *Fatou components of Chebyshev-like maps.* Preliminary report.

Chebyshev-like maps were introduced in the 1980s as multivariable analogues of the Chebyshev polynomials. To each root system in $\mathbb{R}^n$ is associated a sequence of commuting polynomial endomorphisms of $\mathbb{C}^n$. We will discuss the Fatou components of these maps in the cases where the root system is irreducible. (Received September 14, 2013)

1096-37-1327 **Sarah C. Koch*** (kochsc@umich.edu), Department of Mathematics, University of Michigan, 530 Church Street, 2076 East Hall, Ann Arbor, MI 48106. *Eigenvalues and Thurston's theorem.*

Given a postcritically finite rational map on the Riemann sphere, there are several dynamical systems that correspond to it, which naturally arise in the setting of Thurston's topological characterization of rational maps. Associated to each of these dynamical systems is a corresponding linear operator. In this talk we discuss the sets of eigenvalues of these operators and explore connections between them. (Received September 14, 2013)

1096-37-1330 **James Liu*** (liu@math.colostate.edu). *Some dynamical system models for viral protein assembly.* Preliminary report.

In this talk, we present some preliminary results on using dynamical systems for modeling viral assembly. These systems have high dimensions due to the large number of proteins involved in association and dissociation, which also render the polynomial features of these systems. While direct simulations of a single system of monomers all the way up to the capsid can be performed, the roles of lower order multimers such as pentamers and hexamers will be exploited to use cascaded systems for simulations and analysis. This is a joint work with C.Chen, R.Munoz-Alicea, S.Tavener at ColoState, T.Huang at TAMUQ, and Q.Nie at UC Irvine. (Received September 15, 2013)

1096-37-1421 **Steve Kass*** (skass@drew.edu) and **Kathleen Madden**. *A sufficient condition for non-soficness of higher-dimensional subshifts.*

A shift space is called *sofic* if it is a factor of a shift of finite type, and in one dimension, the sofic shifts are completely characterized. In higher dimensions, however, no characterization is known, and for $d > 1$ the literature contains relatively few examples of non-sofic $\mathbb{Z}^d$ subshifts. It is not even known whether the free product $X^{\mathbb{Z}}$ is non-sofic whenever X is.

For $d = 1$, the sofic $\mathbb{Z}^d$ subshifts are characterized in terms of *follower sets,* but there is no direct generalization of follower sets for $d > 1$.

In this work, we define *extender sets*, and we use them to establish a sufficient condition for a $\mathbb{Z}^d$ subshift X to be non-sofic. We apply this condition to a variety of examples, and we show that our condition also implies that $X^{\mathbb{Z}}$ is non-sofic. (Received September 15, 2013)

1096-37-1497 **Don Udita N Katugampola*** (udita@desu.edu), Department of Mathematics, Delaware State University, Dover, DE 19901. *Some Results of A Fractional Population Dynamic Model.*

Certain complex behaviors of natural phenomena, such as spreading a disease or forming a tornado, can not be satisfactorily explained by ordinary dynamical systems. This is mainly because, these complex situations are anomalous in nature and can only be identified by systems, which relax the conditions on the order of derivatives. In this paper, we study the existence of a solution for a certain class of fractional predator-prey model of orders $\alpha, \beta \in (0, 1]$. We also investigate the conditions for the stability of such dynamical systems using the Lyapunov-function analysis. Further, we study the phase portrait of such competition models near critical points. (Received September 16, 2013)

1096-37-1610 **Kelly B Yancey*** (kbyancey1@gmail.com) and **Rachel Bayless**. *Weakly Mixing Vs. Rigid in the Infinite Setting.* Preliminary report.

In the setting of infinite ergodic theory, measure-preserving transformations that are rigid and spectrally weakly mixing are generic in the sense of Barie category. During this talk we will discuss rigid verses various types of weakly mixing in infinite ergodic theory. We will also construct examples of transformations that have these desired properties. Our examples will be via the method of cutting and stacking. (Received September 16, 2013)

1096-37-1701 **Kevin W. O'Neill*** (kevinwoneill@berkeley.edu), Department of Mathematics, University of California, Berkeley, 970 Evans Hall #3840, Berkeley, CA 94720, and **Francis Edward Su** (su@math.hmc.edu), Department of Mathematics, Harvey Mudd College, Claremont, CA 91711. *A combinatorial proof of the Poincaré-Birkhoff Theorem.*

The Poincaré-Birkhoff theorem states that an area-preserving twist homeomorphism of the annulus has at least 2 fixed points. In this paper, we provide a combinatorial proof of the theorem which is similar in spirit to the proof of the Brouwer Fixed Point theorem involving Sperner's Lemma. We define and follow a discrete 'pushing' path, which must end in a nonessential loop of winding number 1, forcing the existence of a fixed point. The process is repeated, following pushing paths from a small neighborhood around the first fixed point. Either one path forms a nonessential loop as before, or a combination of these paths may be pieced together to form such a loop, establishing a second fixed point. Our method is constructive, so we end by discussing its application to computational algorithms. (Received September 16, 2013)

1096-37-1702 **Petko M. Kitanov*** (pkitanov@uoguelph.ca), Dept. of Math & Stats, University of Guelph, Guelph, ON N1G 2W1, Canada, and **William F. Langford** and **Allan R. Willms**. *Double Hopf Bifurcation with Huygens Symmetry.*

A case of coupled oscillators, motivated by the classic problem of synchronization of Huygens' clocks, is studied. It is assumed that the two oscillators are identical and their coupling is symmetric. This type of symmetry is called *Huygens symmetry.* The focus is on the effect that the Huygens symmetry assumption has on the dynamic behavior of the system. It is assumed also that the two oscillators are near the onset of periodic oscillations, via Hopf bifurcations. Then the fundamental role played by the symmetry in determining the dynamic behaviors and bifurcations exhibited by such coupled oscillators is explored, using the Elphick-Huygens normal form presented here. The symmetry profoundly changes the typical behavior of the coupled oscillator system. Many features appear, including the classical in-phase and anti-phase normal modes that are forced by the symmetry, as well as pairs of mixed mode phase-locked periodic solutions. A theorem based on topological degree theory establishes the existence of quasiperiodic solutions in an invariant 3-torus that resembles a 2-torus slightly thickened to a solid toroidal shell, with the two principal radii of the 2-torus slowly modulated in time; that is, a *toroidal breather*. (Received September 16, 2013)

1096-37-1749 **Kevin McGoff*** (mcgoff@math.duke.edu) and **Ronnie Pavlov**. *Random $\mathbb{Z}^d$ subshifts of finite type.* Preliminary report.

For an integer $d \geq 1$ and a finite set $\mathcal{A}$, let $\mathcal{A}^{\mathbb{Z}^d}$ denote the full shift on $\mathcal{A}$. Let $B_n = \mathcal{A}^{[1,n]^d}$ be its set of words with shape $[1,n]^d \subset \mathbb{Z}^d$. Define a random subset ω of B_n by independently choosing each word from B_n with some probability α. Let X_ω be the (random) SFT built from the set ω. For $0 \leq \alpha \leq 1$ and n tending to infinity, we compute the limit of the likelihood that X_ω is empty. For $d \geq 2$, there is no algorithm that decides in finite time whether a given SFT is empty; nonetheless, we find an exact representation of the limiting probability of emptiness in terms of α and the zeta function of $\mathcal{A}^{\mathbb{Z}^d}$. (Received September 17, 2013)

1096-37-1843 **Laura DeMarco**, **Xiaoguang Wang** and **Hexi Ye*** (yehexi@math.utoronto.ca), Department of Mathematics, University of Toronto, Bahen Centre, 40 St. George St., Room 6290, Toronto, Ontario M5S 2E4, Canada. *Torsion anomolous points and the Lattes family.*

We study the marked points $c(t)$ for the Lattes family $f_t(z) = \frac{4tz(z-1)(z-t)}{(z^2-t)^2}$, where $c(t)$ is rational function defined over ¶^{1}. When the coefficients of the rational function $c(t)$ are in some number field, we show that set of t such that $c(t)$ is preperiodic under $f_t(z)$ equidistributes with respect to the bifurcation measure. From this result, we get some known results of Masser and Zannier about the Legendre family of elliptic curves E_t: $\{y^2 = x(x-1)(x-t)\}$ for $t \in \mathbb{C} \setminus \{0,1\}$. (Received September 16, 2013)

1096-37-1853 **M Najafi*** (mnajafi@kent.edu), Kent State University, Ashtabula, OH 44044. *Study of the Solution of the Hyperbolic Systems Analytically Via Decomposition Method.*

We have investigated the stabilization properties of vibrating strings in parallel whose energy is damped out by boundary velocity feedback, via the Modified Adomian Decomposition method (MADM). The approximate solution to these coupled wave equations was studied analytically. Having taken into account the energy of the system, the approximate solutions of this parallel strings with velocity feedback controllers are reasonably close to the benchmark finite difference data. (Received September 16, 2013)

1096-37-1919 **Jane Wang*** (jywang@princeton.edu), **Francisc Bozgan**, **Anthony Sanchez**, **Cesar E Silva** and **David Stevens**. *Weak Rational Ergodicity and Rank-One Transformations.* Preliminary report.

We show that all rank-one infinite measure-preserving transformations are subsequence weakly rationally ergodic and rank-one transformations with a bounded number of cuts are weakly rationally ergodic, extending work of Dai, Garcia, Padurariu, and Silva. We further prove that there exist rank-one transformations that are not weakly rationally ergodic. We also study the properties of zero type and multiple recurrence for rank-one infinite transformations. (Received September 16, 2013)

1096-37-1925 **Mary E. Wilkerson*** (mwilkerso@coastal.edu). *Matings of critically preprediodic quadratic polynomials: dynamics through tile subdivisions.* Preliminary report.

"Mating" is an operation that topologically glues the domains of a polynomial pair in order to obtain a new map on the resulting quotient space. The dynamics of the mated map are then dependent on the two polynomials and the manner in which their domains were glued. In this talk, I will outline a construction using Hubbard trees and finite subdivision rules to examine the dynamics of critically preperiodic quadratic polynomials and their matings: i.e, using tilings to study matings in which two dendritic Julia sets are glued together. We'll then examine how this construction yields information on the topological behavior of the mating and related rational maps. (Received September 16, 2013)

1096-37-1972 **Jonguk Yang*** (jonguk.yang@mail.utoronto.ca), 720 Spadina Avenue, Apt 806, Toronto, Ontario M5S2T9, Canada. *Matings with the Basilica.*

My talk will describe the family of quadratic rational maps with a 2-periodic superattracting orbit. Many of these maps can be described as the mating of two quadratic polynomials, one of which is the basilica. For this reason, the family has attracted much recent attention, and the parameter space picture is now nearly completely understood. I will survey the recent results and the methods behind them. (Received September 16, 2013)

1096-37-2012 **Hao Wu*** (wh45@njit.edu) and **Denis Blackmore** (blackmor@njit.edu). *Investigation of Infinite-Dimensional Dynamical Systems Models Applicable to Granular Flows.*

Recently Blackmore, Samulyak and Rosato developed a class of infinite-dimensional dynamical system in the form of integro-partial differential equations, which have been called BSR models. The BSR models were originally derived to model granular flows, but they actually have many additional applications in a variety of fields. We prove that dynamical systems of the BSR type are well posed under mild auxiliary conditions, and have interesting properties such as complete integrability and wave-like solutions in certain cases. Moreover, there are stable traveling wave solutions for BSR systems having special properties related to physical fields that are important elements of the ω-limit sets of special points in the phase space of dynamical systems. A novel semidiscrete numerical scheme for obtaining approximate solutions has been derived and this can be used to demonstrate the value of BSR models for predicting the evolution of granular flows and other flow field related phenomena.
(Received September 17, 2013)

1096-37-2015 **Jan-Li Lin*** (jlin4@nd.edu). *Rational maps on $\mathbf{P}^2$ with invariant two form, piecewise linear maps on $\mathbf{R}^2$, and the rotation number.*

In this talk I will describe a joint work with Jeff Diller on the dynamics of rational maps on $\mathbf{P}^2$ with the invariant meromorphic two form $\frac{dx\wedge dy}{xy}$. Such a map induces a piecewise linear map on $\mathbf{R}^2$ which maps lattice points to lattice points. It further induces a covering self map on the circle. Assuming that the covering map is a homeomorphism, then an important dynamical property of the rational map called "algebraic stability" is closely related to the rotation number of the circle homeomorphism.

A surprising application of this connection is a new proof of a theorem of E. Ghys and V. Sergiescu: For a circle homeomorphism induced by a piecewise linear map on $\mathbf{R}^2$ preserving lattice points, its rotation number is always a rational number. (Received September 17, 2013)

1096-37-2063 **Andrew-David Bjork*** (abjork@sienaheights.edu) and **Aaron Hill**. *Towards A Complete Understanding Of The Mixing Properties Of Rank-*1 *Cut And Stack Transformations With Bounded Parameters.* Preliminary report.

In the context of rank-1 transformations, we know the following.

- Every rank-1 transformation is ergodic.
- There are rank-1 transformations that are ergodic but not totally ergodic.
- There are rank-1 transformations that are totally ergodic but not weak mixing.
- There are rank-1 transformations that are weak mixing but not strongly mixing.
- There are rank-1 transformations that are strongly mixing, but every such transformation is mixing of all orders.

In general it is difficult to determine where a particular rank-1 transformations fits in this mixing hierarchy. For rank-1 transformations with bounded cutting parameter, the picture is much clearer.

- A rank-1 transformation with bounded cutting parameter cannot be strongly mixing.
- Gao and Hill give an explicit description (based on the cutting and spacer parameters) of those rank-1 transformations with bounded cutting parameter that are totally ergodic.

The main result of this talk completes the picture for rank-1 transformations with bounded cutting and spacer parameters. Theorem: A bounded rank-1 transformation is weakly mixing if and only if it is totally ergodic.
(Received September 17, 2013)

1096-37-2079 **Michael Craig*** (craiginski@yahoo.com), Massachusetts Institue of Technology, 77 Massachusetts Avenue, 1-123, Cambridge, MA 02139, and **Alexander T. Frumosu**. *Calculus in the Mites Program.*

The Minority Introduction to Engineering and Science (MITES) program at MIT is a rigorous, six-week residential program for talented underrepresented high-school juniors interested in pursuing careers in science and engineering. Students in the program study mathematics, physics, humanities and either chemistry, biochemistry or biology. In addition they participate in a hands-on project chosen from robotics, computer programming, electronics, genomics and architecture.

The mathematics component of the program focuses on calculus. Three levels of calculus with topics ranging from pre-calculus to multi-variable calculus are offered. However, the largest group of students study concepts necessary for the fundamental understanding of calculus. MITES prepares these students to approach AP calculus with confidence and provides them with a least a working knowledge of differentiation and integration.

This presentation will provide the concepts introduced, as well as the proven pedagogy that has ensured the success of the MITES program since 1975. (Received September 17, 2013)

1096-37-2090 **Joanna Marie Furno*** (furnoj@dickinson.edu). *Orbit Equivalence Classes of p-adic Transformations.*

For a fixed prime p, we examine the ergodic properties and orbit equivalence classes of p-adic transformations with respect to independent and identically distributed (i.i.d.) product measures other than Haar measure. By calculating ratio sets, we determine the orbit equivalence classes and see possible relationships between the orbit equivalence classes of a transformation and its iterates, with respect to an i.i.d. product measure. (Received September 17, 2013)

1096-37-2094 **Joanna Marie Furno*** (furnoj@dickinson.edu). *Haar Measures and Hausdorff Dimensions of p-adic Julia Sets.* Preliminary report.

Just as the Julia sets of some rational functions on the complex numbers are contained in bounded subintervals of the real line, the Julia sets of some rational functions on the p-adic numbers are contained in the p-adic integers, for a fixed prime p. In this talk, I will give the Haar measures and Hausdorff dimensions for some examples of such p-adic Julia sets. (Received September 17, 2013)

1096-37-2110 **Ilies Zidane*** (ilies.zidane@math.univ-toulouse.fr), Institut de Mathematiques de Toulouse, Universite Paul Sabatier, 118, route de Narbonne, 31062 Toulouse, France. *On the bifurcation locus of cubic polynomials and the size of Siegel disks.*

Yoccoz gave a sufficient arithmetical condition of linearization of fixed points of holomorphic germs with multiplier $\exp(\mathbf{i}2\pi\alpha)$ where α is an irrational number: $f(z) = \exp(\mathbf{i}2\pi\alpha)z + \mathcal{O}(z^2)$. He also proved that this condition is optimal for quadratic polynomials. We will discuss this optimality for cubic polynomials and quadratic rational maps. We will see how is it related to the size of Siegel disks and parabolic implosion/renormalization. This leads to the study of slices of bifurcation locus where some surprising, unexpected and complicated phenomenons occur due to the interaction between the two critical points. We also investigate some virtual slices arising as geometric limits (parabolic enrichment) of dynamical systems.

We seek analogues of *Zakeri* curves (the locus where the two critical points lie at the boundary of the Siegel disk) in these slices, when the rotation number is not of bounded type, and even, for *Cremer* slices. Given a Siegel slice, the logarithm of the conformal radius of the Siegel disk is a subharmonic function, whose Laplacian is therefore a measure which gives a new viewpoint as well as a lot of information. (Received September 17, 2013)

1096-37-2145 **May Mei***, Department of Mathematics, Denison University, P.O. Box 810, Granville, OH 43023-0810. *Modeling Quasicrystals with Substitution Sequences and Tilings.*

The Nobel Prize-winning discovery of quasicrystals has spurred much work in aperiodic sequences and tilings. The symbolic dynamics of sequences invariant under primitive invertible substitutions on two letters underlie our previous work involving one-dimensional discrete Schrödinger operators. Here, we present preliminary numerical experiments conducted by undergraduates at the Summer Math Institute at Cornell under our supervision including numerical data on the spectrum of operators with potentials given by the Thue-Morse sequence and period doubling sequence, as well as numerical data on the spectrum of the discrete Laplacian on the Penrose tiling and octagonal tiling. Furthermore, we will discuss generalizations to more general substitution sequences. (Received September 17, 2013)

1096-37-2318 **Sherry E Scott*** (sscott1008@gmail.com), 2973 N. 55th Street, Milwaukee, WI 53210. *A dynamical systems and harmonic analysis based method for analyzing signals and fluid flows.*

We consider an ergodic theory and harmonic analysis based method, called the ergodicity defect, in applications involving both fluid flows and signals such as segmented blood vessels taken from brain tumor MRA images. The method is used to glean insight on the behavior of the phenomena in terms of how the fluid particle trajectories or signals sample the space. In fluid flows such information can be used to better understand the transport in the flow and for brain tumor MRA images, indications about tumor therapy response can be obtained. (Received September 17, 2013)

1096-37-2391 **Tanya Firsova*** (tanya.firsova@gmail.com), IMS, Mathematics Department, Stony Brook University, Stony Brook, NY 11794. *New Geometric Proof of Lambda Lemma.*

We will discuss a new geometric proof of the Lambda Lemma. We will emphasize the role of pseudoconvexity in the proof. This is a joint work with Eric Bedford. (Received September 17, 2013)

1096-37-2417 **E. Arthur Robinson, Jr.**, **Joseph Rosenblatt** and **Ayşe A. Şahin*** (asahin@depaul.edu). *Recent developments in directional dynamics.* Preliminary report.

We will present some recent developments in the theory of directional dynamics. In particular we will define directional ergodicity and directional weak mixing and show the possible range of directional behavior in these categories for finite measure preserving, ergodic $\mathbb{Z}^2$ actions. (Received September 17, 2013)

1096-37-2444 **Elana J Fertig*** (ejfertig@jhmi.edu), 550 N Broadway, Suite 1101E, Baltimore, MD 21209, and **Dane Taylor**, **Matthew R Francis** and **Juan G Restrepo**. *Dynamics in hybrid complex systems of switches and oscillators.*

Complex network dynamics have been analyzed for systems of coupled switches or systems of coupled oscillators. However, many complex systems are composed of components with diverse dynamics whose interactions drive the system's evolution. We, therefore, introduce new modeling frameworks for networks composed of both oscillators and switches. Simulations show that these models lead to novel dynamics not found in systems of only switches or oscillators. Depending on the choice of parameters, we find theoretically coexisting stable solutions with either (i) incoherent oscillators and all switches permanently off, (ii) synchronized oscillators and all switches permanently on, or (iii) synchronized oscillators and switches that periodically alternate between the on and off states. Transitions between these steady state solutions can be onset deterministically through dynamic bifurcations or spontaneously due to finite-size fluctuations. (Received September 17, 2013)

1096-37-2590 **Laura G DeMarco*** (demarco@uic.edu). *Analytic and algebraic stability.* Preliminary report.

I will describe joint work with Xander Faber. We study relations between the dynamics of rational maps on $\mathbf{P}^1$ (in families), dynamics on the Berkovich projective line, the dynamics of meromorphic maps on surfaces, and a countable-state Markov process, all under a stability hypothesis. The main new result is that this stability can always be achieved by a suitable modification. (Received September 17, 2013)

1096-37-2676 **Remus Radu*** (rradu@math.sunysb.edu), Institute for Mathematical Sciences, Stony Brook, NY 11794, and **Raluca Tanase** (rtanase@math.sunysb.edu), Institute for Mathematical Sciences, Stony Brook, NY 11794. *A structure theorem for semi-parabolic Hénon maps.*

Consider the parameter space $\mathcal{P}_\lambda \subset \mathbb{C}^2$ of complex Hénon maps

$$H_{c,a} = (x^2 + c + ay, ax), \quad a \neq 0$$

which have a semi-parabolic fixed point with one eigenvalue $\lambda = e^{2\pi i p/q}$. We give a structure theorem for those Hénon maps from the curve $\mathcal{P}_\lambda$ that are small perturbations of a quadratic polynomial p with a parabolic fixed point of multiplier λ. We prove that there is an open disk of parameters (inside $\mathcal{P}_\lambda$) for which the semi-parabolic Hénon map is structurally stable on the Julia sets J and J^+. The set J^+ in the bidisk $\mathbb{D} \times \mathbb{D}$ is a trivial fiber bundle over J_p, the Julia set of the polynomial p, with fibers biholomorphic to $\mathbb{D}$. The set J is homeomorphic to a solenoid with identifications, hence connected.

This generalizes the theorem of Hubbard and Oberste-Vorth (which characterizes Hénon maps that are perturbations of a hyperbolic polynomial) to the semi-parabolic setting. The technique of the proof is quite new and is inspired by the proof of Douady and Hubbard that the Julia set of a parabolic polynomial is locally connected. (Received September 17, 2013)

1096-37-2700 **J Santanilla***, University Of New Orleans, Department of Mathematics, New Orleans, LA 70121. *Positive solutions for nonlinear stochastic differential equations.* Preliminary report.

In certain population and biological models it is natural to study positive solutions for the associated equations. Typically those equations are nonlinear differential equations of various types and frequently they involve some randomness. We discuss the question of existence of positive solutions for nonlinear stochastic differential equations. (Received September 18, 2013)

39 ► Difference and functional equations

1096-39-56 **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. *Existence of positive solutions for a system of second order multipoint discrete boundary value problems.*

We investigate the existence of positive solutions for a system of nonlinear second order difference equations subject to multipoint boundary conditions. (Received June 26, 2013)

1096-39-150 **Chris D. Lynd*** (clynd@bloomu.edu), Bloomsburg, PA 17815. *A Subclass of Anti-Competitive Systems Of Two, First-Order, Rational Linear Difference Equations.*

If you have system of equations that has a corresponding map F that is anti-competitive, then F^2, the square of the map, is competitive. There are 289 systems of two first-order rational linear difference equations that have a corresponding map F that is anti-competitive for all positive values of its parameters. For 112 of these systems, the map F^2 is *strongly* competitive. We will present a theorem that describes the global behavior of the solutions for all 112 systems in this subclass of anti-competitive systems. (Received August 26, 2013)

1096-39-393 **John Wesley Cain*** (jcain2@richmond.edu,jcain2@math.harvard.edu), University of Richmond (Mathematics and CS), Harvard University (Mathematics), and **Shuang Zhao** (shuang.zhao@richmond.edu) and **Kathryn G Workman** (kate.workman@richmond.edu). *Restricted Feedback Control and Discrete-Time Dynamical Systems.*

Bifurcations can destabilize equilibria of physical or biological systems, potentially causing undesirable oscillatory or chaotic behavior. By applying small perturbations to an accessible parameter (e.g., via closed-loop feedback), it may be possible to stabilize an otherwise unstable equilibrium. Here, we shall derive criteria under which such control is possible for discrete-time systems of the form $x_n = f(x_{n-1}, x_{n-2}, \ldots, x_{n-k}; \mu)$, where μ is the accessible parameter. Importantly, we shall distinguish between whether or not μ may be perturbed for every n, motivated by an example involving cardiac rhythm. (Received September 01, 2013)

1096-39-437 **Allan Peterson*** (apeterson1@math.unl.edu), University of Nebraska-Lincoln, 237 Avery, Lincoln, NE 685880130. *Calculus on Mixed Time Scales.*

An introduction to the so-called discrete calculus on mixed time scales will be given. The appropriate Taylor monomials and Taylor's formula will be presented. This will give us a variation constants formula for the difference equations involving functions defined on a mixed time scale. Finally, the theory of Laplace transforms for functions on mixed time scales will be developed. (Received September 03, 2013)

1096-39-439 **Allan Peterson*** (apeterson1@math.unl.edu), University of Nebraska-Lincoln, 237 Avery, Lincoln, NE 685880130. *Nabla Fractional Difference Equations.*

We will introduce the discrete nabla fractional calculus. The basic functions in the nabla calculus will be given along with several of their properties. Taylor monomials and a Taylor formula will be given. The Mittag-Leffler function and its use to solving non-homogeneous fractional nabla difference equations will be presented. (Received September 03, 2013)

1096-39-477 **Daniel W. Cranston*** (dcranston@vcu.edu) and **Candace M. Kent**. *Boundedness of Solutions of the Difference Equation $x_n = \max\left\{\frac{A^1_{n-1}}{x_{n-1}}, \frac{A^2_{n-1}}{x_{n-2}}, \ldots, \frac{A^t_{n-1}}{x_{n-t}}\right\}$ with Periodic Parameters.*

We investigate the boundedness of positive solutions of the reciprocal max-type difference equation

$$x_n = \max\left\{\frac{A^1_{n-1}}{x_{n-1}}, \frac{A^2_{n-1}}{x_{n-2}}, \ldots, \frac{A^t_{n-1}}{x_{n-t}}\right\}, \quad n = 1, 2, \ldots,$$

where, for each value of i, the sequence $\{A^i_n\}_{n=0}^{\infty}$ of positive numbers is periodic with period p_i. We give both sufficient conditions on the p_i's for the boundedness of all solutions and sufficient conditions for all solutions to be unbounded. This work essentially complements the work by Bidwell and Franke, who showed that as long as every positive solution of our equation is *bounded*, then every positive solution is eventually periodic, thereby leaving open the question as to when solutions are bounded. (Received September 04, 2013)

1096-39-554 **Tim Austin*** (tim@cims.nyu.edu), Courant Institute, New York University, 251 Mercer St, New York, NY 10012. *Partial difference equations over compact Abelian groups.*

Given a compact Abelian group Z, an element z of that group, and a measurable function from it to another such group, one can form a new function by taking the difference of the original function and its translate by z. This is the obvious discrete analog of differentiation, and defines an operator on functions called a differencing operator.

Recent work in additive combinatorics, related to Gowers' proof of Szemerédi's Theorem, leads naturally to the study of certain 'higher-order' partial difference equations involving such operators. Given several elements of Z, one asks for a description of those functions on Z which vanish when one applies all of the resulting differencing operators. It turns out that as the order of the difference equation increases, one can sometimes find surprising extra structure among these solutions, which amounts to a first step towards understanding the inverse problem for the 'directional Gowers norms'. (Received September 05, 2013)

1096-39-556 **Ralph Willox*** (willox@ms.u-tokyo.ac.jp), **Alfred Ramani**, **Basil Grammaticos** and **Junkichi Satsuma**. *An IST-like solution to the Cauchy problem for a soliton cellular automaton.*

By analogy with the well-known IST scheme for the Korteweg-de Vries (KdV) equation, we define spectral data for an extended solitonic cellular automaton related to the KdV equation through ultradiscretization. In particular, it will be explained how the evolution of the spectral data that correspond to solitons is defined in terms of an ultradiscrete squared eigenfunction, while the remaining data are found to satisfy a linearized version of the cellular automaton. The scheme we present offers a solution to the Cauchy problem for the ultradiscrete KdV equation, defined over the real numbers, in almost perfect analogy with the continuous case. (Received September 05, 2013)

1096-39-573 **Raghib M. Abu-Saris*** (rabusaris@yahoo.com), rabusaris@yahoo.com. *Advances in Asymptotic Periodicity of Nonlinear Difference Equations.*

We review recent results that present necessary and/or sufficient conditions for all solutions of a nonlinear difference equation to be asymptotically periodic, i.e., attracted to periodic solutions of the same period. In addition, applications of the aforementioned conditions will then be demonstrated. Furthermore, the talk will culminate in future research projects. (Received September 16, 2013)

1096-39-574 **Jeffrey W Lyons*** (jlyons@nova.edu), FAR-MCT, Nova Southeastern University, 3301 College Avenue, Fort Lauderdale, FL 33314. *Existence of Antisymmetric Solutions for Second Order Difference Equations with Antiperiodic Boundary Conditions.*

An Avery type fixed point theorem is applied to a second order difference equation with antiperiodic boundary conditions to show the existence antisymmetric solutions. (Received September 06, 2013)

1096-39-663 **saber N elaydi***, One Trinity Place, San Antonio, TX 78212, and **E Balreira** and **R Luis**. *Global Dynamics of Triangular maps.*

We consider continuous triangular maps on I^N, where I is a compact interval in the Euclidean space $\mathbb{R}$. It is shown that every orbit converges to a fixed point if and only if there are no periodic orbit of prime period 2. As a consequence we obtain the following global stability result: if there are no periodic orbits of prime period 2 and the triangular map has a unique fixed point, then the fixed point is globally asymptotically stable. (Received September 08, 2013)

1096-39-710 **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. *Local Qualitative Behavior of Discrete Dynamical Systems with Non-hyperbolic Equilibria: a Special Case.*

We consider the local qualitative behavior of solutions to autonomous planar difference equations in a neighborhood of an isolated non-hyperbolic fixed point whose associated characteristic root is 1 with geometric multiplicity two.

Some results are established which are analog to those by A. A. Andronov about the local qualitative behavior of non-hyperbolic equilibria of autonomous differential equations. (Received September 09, 2013)

1096-39-715 **Laila Assas*** (aslaila201@yahoo.com), **S Elaydi**, **E Kwessi**, **G Livadiotis** and **D Ribble**. *On the stability and bifurcation of A predator-prey model with Allee effect.* Preliminary report.

We consider a predator-prey model with refuge that possesses the Allee effect. The most common type of spatial refuge is when a constant proportion of the prey population is protected from predation. In this talk, we investigate the local and global dynamics of the model. This includes, among other things, an investigation of bifurcation and invariant manifolds. (Received September 09, 2013)

1096-39-772 **Ronald E. Mickens*** (rmickens@cau.edu), Clark Atlanta University, Box 1744-, Physics Department, Atlanta, GA 30314. *Global Dynamics and Bifurcation of Difference Equations.*

In general, an arbitrary differential equation does not have solutions expressible in terms of a finite combination of elementary functions and, as a consequence, must be discretized to determine numerical solutions. Numerical Instabilities (NI) are solutions to the discretized equations which have no correspondence to solutions of the original differential equations. We show, through explicit examples, that NI's are bifurcation phenomena. They arise from the fact that the parameter space of the discrete equations is always greater than the parameter space of the differential equations. These additional parameters arise from the introduction of time and/or space step-sizes in the construction of the discrete-derivative analogs of the continuous derivatives. We demonstrate that the Nonstandard Finite Difference (NSFD) methodology of Mickens can be used to eliminate NI's for (at least) first-order ODE's. For these equations there are three types of mechanisms for the occurrence of NI's (bifurcations); we label them "threshold", "order", and "creation" bifurcations. These two references provide the background required to comprehend our presentation. (Received September 10, 2013)

1096-39-778 **Vlajko L. Kocic*** (vkocic@xula.edu), Mathematics Department, Xavier University of Louisiana, 1 Drexel Dr., New Orleans, LA 70125, and **Yevgeniy Kostrov** (ykostrov@xula.edu), Mathematics Department, Xavier University of Louisiana, 1 Drexel Dr., New Orleans, LA 70125. *On the Dynamics of Discontinuous Discrete Beverton-Holt Model.*

We study the dynamics of the discontinuous discrete Beverton-Holt model. (Received September 10, 2013)

1096-39-889 **Jim M Cushing*** (cushing@math.arizona.edu), Department of Mathematics, University of Arizona, 617 N Santa Rita, Tucson, AZ 85721. *A difference equation model for the evolutionary dynamics of a population subject to a strong Allee effect.* Preliminary report.

A prototype difference equation for the dynamics of a population subject to a strong Allee effect is extended so as to include Darwinian adaptation. The resulting mathematical model is a planar system of nonlinear difference equations. Some results about the asymptotic dynamics of this Darwinian model will be given. The ecological goal is to see in what way the ability to evolutionarily adapt might affect the fate of a population that is endangered by the presence of an Allee threshold. (Received September 11, 2013)

1096-39-900 **Youssef Naim Raffoul*** (yraffoul1@udayton.edu), University of Dayton, 200 College Park, Dayton, OH 45469-2316. *Qualitative Analysis of Solutions of Functional Difference Equations.*

We consider a functional difference equation and use fixed point theory to obtain necessary and sufficient conditions for the asymptotic stability of its zero solution. At the end of the paper we apply our results to nonlinear Volterra infinite delay difference equations.
(Received September 11, 2013)

1096-39-997 **Anton Dzhamay** (anton.dzhamay@unco.edu) and **Tomoyuki Takenawa*** (takenawa@kaiyodai.ac.jp). *Schlesinger transformation and discrete Painlevé equation of type $A_1^{(1)*}$.* Preliminary report.

Schlesinger transformations are algebraic transformations of a Fuchsian system that preserve its monodromy representation and act on the characteristic indices of the system by integral shifts. One of the important reasons to study such transformations is the relationship between Schlesinger transformations and discrete Painlevé equations. The Fuchsian systems were classified by Ohshima recently by their spectral types and transformations so called additions and middle convolutions. In the previous study, we showed how to write an elementary Schlesinger transformation as a discrete Hamiltonian system w.r.t. the standard symplectic structure on the space of Fuchsian systems. We then showed how Schlesinger transformations reduce to discrete Painlevé equations of type $D_4^{(1)}$ (or difference Painlevé V) and type $A_2^{(1)*}$. In this talk, we extend our previous results to discrete Painlevé equations of type $A_1^{(1)*}$ and explicitly show how to obtain the equations of this type as reductions of Schlesinger transformations. (Received September 12, 2013)

1096-39-1023 **Candace M. Kent*** (cmkent@vcu.edu), 3510 Hanover Avenue, Richmond, VA 23221-2208, and **Michael A. Radin**. *On the Boundedness of Positive Solutions of a Reciprocal Max-Type Difference Equation with Periodic Parameters.*

We investigate the boundedness of positive solutions of the reciprocal max-type difference equation

$$x_{n+1} = \max\left\{\frac{A_n}{x_{n-k}}, \frac{B_n}{x_{n-\ell}}\right\}$$

with positive periodic parameters and arbitrary delays. We give sufficient conditions on parameters and their periods for every solution to be unbounded. We also introduce the idea of *extended periodicity*of unbounded solutions, and then give sufficient conditions on the delays such that particular patterns of the extended periodicity of unbounded solutions are obtained. (Received September 12, 2013)

1096-39-1189 **John R Greene*** (jgreene@d.umn.edu), Department of Mathematics and Statistics, 140 Solon Campus Center, 1117 University Drive, Duluth, MN 55812. *A number theoretic twist on second order recurrence relations.* Preliminary report.

Consider the following nonlinear variation on the Fibonacci sequence: $a_0 = 1$, $a_1 = 1$, and for $n \geq 2$,

$$a_n = \begin{cases} \frac{a_{n-1}+a_{n-2}}{5}, & \text{if this is an integer,} \\ a_{n-1}+a_{n-2}, & \text{otherwise.} \end{cases}$$

This sequence proceeds 1, 1, 2, 3, 1, 4, 1, 1, . . . , and is periodic of length 6. This sequence is quite special. With initial conditions $a_0 = 1$, $a_1 = 3$, the resulting sequence grows without bound. Change the 5 in the denominator and the pattern changes as well. It appears that 2, 3, 5 are the only (positive) denominators which allow periodic sequences. To generalize, fix integers P, Q and a rational number r. We investigate periodic behavior for sequences of the form

$$a_n = \begin{cases} r(Pa_{n-1} - Qa_{n-2}), & \text{if this is an integer,} \\ Pa_{n-1} - Qa_{n-2}, & \text{otherwise.} \end{cases}$$

(Received September 13, 2013)

1096-39-1212 **Winfried Just** and **German A. Enciso***, 440E Rowland Hall, University of California, Irvine, Irvine, CA 92697. *Ordered Dynamics in Biased and Cooperative Boolean Networks.*

This paper contributes to the theoretical analysis of the qualitative behavior of two types of Boolean networks: biased and cooperative ones. A Boolean network is biased if at least a specified fraction of its regulatory functions returns one Boolean value more often than the other and is cooperative if there are no negative interactions between the variables. We prove nontrivial upper bounds on the maximum length of periodic orbits in such networks under the assumption that the maximum number of inputs and outputs per node is a fixed constant r. For the case of n-dimensional networks with $r = 2$ in which only AND and OR are allowed, we find an upper bound of $10^{n/4}$, which is asymptotically optimal in view of previously published counterexamples. The theoretical results are supplemented by simulations of the generic behavior of cooperative networks which indicate that for large in-degrees, trajectories tend to converge rapidly towards a steady state or small periodic orbit. The latter starkly contrasts with the behavior of random arbitrary Boolean networks. (Received September 13, 2013)

1096-39-1280 **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 14, 2013)

1096-39-1366 **Eddy A Kwessi***, One Trinity Place, San Antonio, TX 78212, **Saber Elaydi** (selaydi@trinity.edu), One Trinity Place, San Antonio, TX 78212, **George Livatiodis** (glivatiodis@swri.edu), 6220 Culebra Road, San Antonio, TX 78238, **David Ribble** (dribble@trinity.edu), One Trinity Place, San Antonio, TX 78212, and **Laila Assas** (aslaila@uq.edu.sa), Department of Mathematics, Collge of Applied Sciences, Makkah, 10265, Saudi Arabia. *Stochastic Persistence in a Contest-Competition Model with Allee Effect.* Preliminary report.

In this talk, we will investigate the stochastic persistence in a two-dimensional contest-competition model with Allee effect. We will also address stochastic persistence despite small and large perturbations for interacting populations. (Received September 15, 2013)

1096-39-1537 **jasmin bektesevic**, university of sarajevo, 71000 sarajevo, Bosnia-Herzegovina, **mustafa r.s. kulenovic***, university of rhode island, kingston, RI 02881, and **esmir pilav**, university of sarajevo, 71000 sarajevo, Bosnia-Herzegovina. *Global Dynamics of Quadratic Second Order Difference Equation in the First Quadrant.*

We investigate the global behavior of a quadratic second order difference equation

$$x_{n+1} = Ax_n^2 + Bx_nx_{n-1} + Cx_{n-1}^2 + Dx_n + Ex_{n-1} + F, \quad n = 0, 1, \ldots$$

with non-negative parameters and initial conditions. We find the global behavior for all ranges of parameters and determine the basins of attraction of all equilibrium points. We also give all possible bifurcation for this equation. (Received September 16, 2013)

1096-39-1540 **mark DiPippo**, university of rhode island, kingston, RI 02881, **ed j. janowski**, university of rhode island, kingston, 02881, and **mustafa r.s. kulenovic***, university of rhode island, kingston, RI 02881. *Global Asymptotic Stability for Quadratic Fractional Difference Equation.* Preliminary report.

Consider the difference equation

$$x_{n+1} = \frac{\alpha + \sum_{i=0}^{k} a_i x_{n-i} + \sum_{i=0}^{k}\sum_{j=i}^{k} a_{ij} x_{n-i}x_{n-j}}{\beta + \sum_{i=0}^{k} b_i x_{n-i} + \sum_{i=0}^{k}\sum_{j=i}^{k} b_{i,j} x_{n-i}x_{n-j}}, \quad n = 0, 1, \ldots$$

where all parameters $\alpha, \beta, a_i, b_i, a_{i,j}, b_{i,j}, i, j = 0, 1, \ldots, k$ and the initial conditions $x_i,\ i \in \{-k, \ldots, 0\}$ are nonnegative. We investigate the asymptotic behavior of the solutions of the considered equation. We give simple explicit conditions for the global stability and global asymptotic stability of the zero or positive equilibrium of this equation. (Received September 16, 2013)

1096-39-1652 **Heather B Hunt*** (hbhunt01@louisville.edu), University of Louisville, Department of Mathematics, 328 Natural Sciences Building, Louisville, KY 40292, and **Prasanna K Sahoo**. *A Generalized Linear Functional Equation Defined on Groups.*

Let G be any arbitrary group and $\mathbb{C}$ the field of complex numbers. We will present all functions $f, g, h, k : G \times G \to \mathbb{C}$ that satisfy the functional equation

$$f(pr, qs) + g(ps, qr) = h(p, q) + k(r, s)$$

for all $p, q, r, s \in G$. In order to do so, we need the general solution of three important functional equations, namely,

$$f(pr, qs) + f(ps, qr) = 2\,f(p, q) + 2\,f(r, s) \qquad \forall\ p, q, r, s \in G,$$
$$f(pr, qs) + f(ps, qr) = 2\,f(p, q) + f(r, s) + f(s, r) \qquad \forall\ p, q, r, s \in G \qquad \text{and}$$
$$f(pr, qs) - f(ps, qr) = f(r, s) - f(s, r) \qquad \forall\ p, q, r, s \in G.$$

(Received September 16, 2013)

1096-39-1662 **Karyn L Sutton*** (sutton@louisiana.edu). *Computational Aspects of the Estimation of Distributed Delays.*

Past events often affect the current state of many biological, sociological, and physical systems, thus the study of dynamical systems involving delays arises naturally. Delay systems provide a means to account for these past events, which often times are better described by a distribution in the event that there is variability in the time at which they occur. Given observations of such systems, parameter estimation has proven to be a powerful tool to provide insight into the workings of the underlying processes. Mathematically, the numerical computation of such solutions (the forward problem) requires approximation of the infinite dimensional system, and convergence to the true solutions must be considered. Computation of the inverse problem, or estimation of model quantities from observations of the model output, raises further compounding issues, which we discuss here. We present a study of the estimation of distributions, focusing on those which commonly arise in biological systems. We discuss conditions under which one may have confidence in estimation results, and problems and pitfalls often encountered. (Received September 16, 2013)

1096-39-1676 **Christopher M Ormerod*** (cormerod@caltech.edu), Department of Mathematics, California Institute of Technology, 1200 E California Blvd, Pasadena, CA 91125. *Twisted reductions of integrable lattice equations, and their Lax representations.*

We consider reductions of autonomous and non-autonomous lattice equations satisfying a self-similarity constraint, which generalizes the notion of periodic reductions. As examples of this theory, we will present new reductions of the discrete potential Korteweg-de Vries equation, discrete modified Korteweg-de Vries equation and the discrete Schwarzian Korteweg-de Vries equation. We will describe a direct method for obtaining Lax representations for the given reductions. (Received September 16, 2013)

1096-39-1724 **H. Sedaghat*** (hsedagha@vcu.edu). *Reducibility of Planar Systems.* Preliminary report.

A significant variety of planar systems of difference equations such as

$$\begin{cases} x_{n+1} = ax_n + by_n \\ y_{n+1} = x_n^2 - ay_n \end{cases} \quad \text{or} \quad \begin{cases} x_{n+1} = x_n y_n \\ y_{n+1} = (a + bx_n)/y_n \end{cases}$$

that exhibit complex dynamics and sequences of bifurcations in open regions of the plane are reducible in the sense that their orbits within those regions may be obtained from first-order difference equations. The relationship between the solutions of the first-order surrogate and the orbits of the original system is generally complex owing to a number of possible issues, such as the non-invariance of the open region on which the first-order equation is related to the system, restrictions on domains or ranges of functions or the manner in which orbits of the system are constructed from the solutions of the first-order equation. We give a general characterization of reducible systems and discuss some of the issues pertaining to them. (Received September 16, 2013)

1096-39-2097 **Justin Wright*** (jw1018@plymouth.edu). *Weak Enveloping and Global Attractors for Periodic Dynamical Systems.* Preliminary report.

Periodically forced difference equations and their application to population biology have been a topic of interest within the dynamical systems community over the past decade. It has been previously established that P. Cull's concept of an enveloping function can be used to guarantee the global stability of a fixed point for a periodic dynamical system of population models. We extend our work to a class of functions that are more general than population models using a generalized concept of enveloping. We use this concept to show that a periodic dynamical system of perturbations of a hyperbolic population model has a globally attracting geometric cycle. (Received September 17, 2013)

1096-39-2212 **Mingfei Li** (mli@bentley.edu), 175 Forest St., Waltham, MA 02452, and **Mihaela Predescu***, 175 Forest St., Waltham, MA 02452. *Dynamics and Estimation of Parameters in a Discrete Time Model linking Unemployment and Inflation.*

We will discuss the stability properties of solutions of a discrete time model that links short run inflation and unemployment. A statistical model that involves random errors is constructed and then used for parameter estimation and prediction. (Received September 17, 2013)

1096-39-2268 **Kenichi Maruno*** (kmaruno@utpa.edu) and **Jarmo Hietarinta**. *The pentagram map and the discrete Boussinesq equation.* Preliminary report.

The pentagram map that associates to a projective polygon a new one formed by intersections of short diagonals was introduced by R. Schwartz in 1992. Recently, it has attracted much attention. In this talk, we investigate the pentagram map from the point of view of discrete integrable systems. We derive the pentagram map as a 3-reduction of the Hirota-MIwa equation and construct the N-soliton solution. We compare the pentagram map with other discrete Boussinesq equations. (Received September 17, 2013)

1096-39-2307 **Mikheil Tutberidze*** (mikheil.tutberidze@iliauni.edu.ge), Ilia State University, 3/5 Kakutsa Cholokashvili ave., 0162 Tbilisi, Rep of Georgia, and **Soso Pipia** (sosopipia@gmail.com), Delta Systems, 2 Gaprindauli str., 0154 Tbilisi, Rep of Georgia. *On the discrete analogous to one initial-boundary value problem to nonlinear diffusion equation.*

In the presented work the initial-boundary value problem to one nonlinear parabolic equation is considered. For the considered problem the equivalent initial-boundary value problem is obtained to which the difference scheme is constructed. For mentioned difference scheme the theorem of existence of its solution and the theorem of convergence of its solution to the solution of the source problem are proved under some restrictions. The rate of convergence is established and it is equal to $O\left(\tau + h^2\right)$. The corresponding numerical experiments were conducted which confirmed the validity of the theorems. (Received September 17, 2013)

1096-39-2447 **Christopher S. Goodrich*** (cgoodrich@mail.uri.edu), University of Rhode Island, Department of Mathematics, 5 Lippitt Road, Kingston, RI 02881. *Surprising Properties of Fractional Difference Operators.*

In this talk we will begin by providing an introduction to the discrete fractional calculus. We will then provide a few examples, mainly related to the theory of fractional difference equations, to illustrate the many surprising properties of discrete fractional operators. We will conclude by detailing a few open questions regarding the discrete fractional calculus. (Received September 17, 2013)

1096-39-2571 **Talitha M. Washington*** (talitha.washington@howard.edu), Howard University, Department of Mathematics, Washington, DC 20059, and **Ronald E. Mickens** (rmickens@cau.edu), Clark Atlanta University, Department of Physics, Atlanta, GA 30314. *Nonstandard Finite Difference Discretizations of Population Models Satisfying Conservation Laws.*

In this talk, we consider the roles conservation laws can play in providing restrictions on the construction of finite difference discretizations of interacting population systems, modeled by coupled ordinary differential equations. Our analysis is formulated within the nonstandard finite difference (NSFD) methodology of Ronald Mickens. Using a number of well-known population models, we illustrate the details of our procedures by constructing appropriate NSFD discretizations. The relevance of these results to various issues associated with the numerical integration of the original population system differential equations is also presented, especially the role of positivity of the solutions. This is joint work with Ronald Mickens. (Received September 17, 2013)

1096-39-2584 **Emma Smith Zbarsky*** (smithzbarskye@wit.edu). *Dynamics of a two patch gravity model.*

In spatial population models, it can be important to include a factor expressing the difficulty of movement between loci. In this paper we consider a model based on gravitational attraction, where the expectation of the rate of dispersal between patches i and j is $E(T_{i,j}) \propto n_i^\alpha n_j^\beta d_{i,j}^{-\theta}$, where n_i and n_j are the populations of patches i and j and $d_{i,j}$ is some measure of difficulty. The standard model of gravity takes $\alpha = \beta = 1$ and $\theta = 2$. We explore the dynamics of such a system as α, β and θ vary with respect to each other. We find both a pitchfork bifurcation and a period doubling bifurcation, as well as a switch between monotonic and oscillatory behavior. (Received September 17, 2013)

1096-39-2662 **Harold M Hastings*** (hhastings@simons-rock.edu), MA. *Applications of stability analysis of model ecosystems to problems in sustainability and collapse.* Preliminary report.

We shall use stability analysis of model ecosystems to develop a framework to study and hopefully forecast sustainability and collapse. (Received September 17, 2013)

40 ► Sequences, series, summability

1096-40-679 **Jeff Connor*** (connorj@ohio.edu), Department of Mathematics, Ohio University, Athens, OH 45701, and **Ekrem Savas**, Istanbul Ticaret University, Istanbul, Turkey. *Lacunary Statistical and Sliding Window Convergence for Measurable Functions.* Preliminary report.

A class of summability methods, called sliding window methods, for measurable real valued functions defined on $[0, \infty)$ is introduced. These methods are based on the methods of statistical convergence and lacunary statistical summability for sequences. Analogs of inclusion and consistency theorems for the sequential methods are established, along with examples, and a Cauchy criteria is given. (Received September 09, 2013)

41 ► Approximations and expansions

1096-41-779 **Jeff Ledford*** (jpledford@vcu.edu), Department of Mathematics, 1015 Floyd Avenue, P. O. Box 842014, Richmond, VA 23284. *Regular Families of Interpolators on Scattered Data.*

This talk will focus on interpolation of scattered samples of Paley-Wiener functions. We will use families of interpolants, called regular families of interpolators, which allow for limits to be taken. We show that the limit is the original Paley-wiener function. (Received September 10, 2013)

1096-41-1546 **Tariq M Qazi***, Department of Mathematics & Computer Science, Virginia State University, Petersburg, VA 23806. **Mean value of entire functions of exponential type**. Preliminary report.

Let f be an entire function of exponential type τ. From the Bernstein's inequality, we know that $|f'(x)| \leq M\tau$ if $|f'(x)| \leq M$ on the real axis. The p^{th} mean of f on a horizontal line is defined by $M^p(x+iy) := \limsup_{T\to\infty} (1/T) \int_{-T}^{T} |f(x+iy)|^p \, dx$. Harvey [A. R. HARVEY, *The mean of a function of exponential type*, American Journal of Mathematics **70** (1948), 181–202] proved the analogue of Bernstein's inequality for entire functions of exponential type with bounded mean. We will discuss the refinement of Harvey's result for entire function of exponential type f such that $f(z) \equiv \mathrm{e}^{\mathrm{i}\tau z} f(-z)$ under certain restriction on its zeros. (Received September 16, 2013)

1096-41-1644 **Christian Gerhards*** (gerhards.christian@gmail.com), University of Kaiserslautern, Department of Mathematics, 67653 Kaiserslautern, Germany. *Optimized kernels for the combination of global and local data on different spheres.*

Nowadays, a large amount of global satellite data is available for gravity and geomagnetic field modeling. The ill-posed problem of downward continuation, however, renders the reconstruction of strongly localized features at the Earth surface problematic. Data directly collected at the Earth surface does not suffer from this problem. But since surface data is typically only available locally, it is less suited for the reconstruction of global features. Thus, a combination of satellite data with surface data becomes necessary to obtain accurate models.

In this talk, we address the problem based on a multiscale approach with optimized convolution kernels (assuming a spherical satellite orbit and Earth surface). The optimization is done in such a way that the kernels at the lower scales behave well for the downward continuation of satellite data while the kernels at the higher scales have a good spatial localization, i.e., they pay tribute to the local availability of surface data. This allows a smooth combination of both types of data and does not require the patching of two separate (global and local) models. We want to indicate the geophysical background as well as the mathematical aspects of this approach together with numerical tests indicating its performance. (Received September 16, 2013)

1096-41-1690 **AMIT SETIA*** (amitsetia@goa.bits-pilani.ac.in), Department of Mathematics, BITS – Pilani, K. K. Birla Goa Campus, Zuarinagar, Goa 403726, India. *Numerical method to solve fractional Integro-differential equation using Wavelet.*

The use of fractional differential and integral equations in Mathematical models has taken a great impetus in the recent years. And, very often the exact solution to these equations is not available by analytic methods. Then one needs to go for the numerical methods for obtaining the approximate solution. In this talk I would like to enlighten a numerical method to solve a fractional Fredholm integro-differential equation of second kind using wavelet. The wavelet basis finally reduces the Fredholm integro-differential equation of second kind in the system of equations which can be solved to get the approximate solutions. The test examples are taken to show the robustness of the method. (Received September 16, 2013)

1096-41-1804 **Mark A Spanier***, NDSU Mathematics Dept #2750, PO Box 6050, Fargo, ND 58108-6050. *Beurling-Selberg Extremal Problems in de Branges Spaces.*

The classical Beurling-Selberg extremal problem looks at finding optimal entire functions of a given exponential type that majorize or minorize a real valued function while minimizing the $L^1(\mathbb{R})$-norm of the difference.

For a Hermite-Biehler function E, we generalize the Beurling-Selberg extremal problem by replacing the $L^1(\mathbb{R})$-norm with the $L^1(\mathbb{R}, |E(x)|^{-2}dx)$-norm. The theory of de Branges spaces allows us to solve this problem for a class of even functions which includes the Poisson kernel. By specializing the de Branges space, we obtain a solution to the extremal problem for the signum function where the majorant and minorant vanish at a given point on the imaginary axis. This talk contains joint work with Friedrich Littmann. (Received September 16, 2013)

1096-41-2190 **Kendall A Gillies*** (kendall.gillies@ttu.edu) and **Clyde F Martin**. *Using Osculatory Smoothing Splines To Approximate The Solutions To Ordinary Differential Equations.* Preliminary report.

Using techniques from optimal control and control theoretic splines new methods are developed for the numerical solutions of ordinary differential equations. A new formulation of smoothing splines is developed based on osculatory interpolation. This involves two smoothing parameters. An nth order linear multi-point method is used and this has 2n-1 parameters. The multi-point algorithm is used to generate a set of data points that approximate the solution of the differential equation $\dot{x} = f(x,t)$. The data set is smoothed using the spline, y(t).

Then the integral

$$\int_0^T (\dot{y}(t) - f(y(t), t))^2 dt$$

is minimized with respect to the 2n+1 parameters creating an optimal multi-point algorithm for the particular differential equation. (Received September 17, 2013)

42 ► Fourier analysis

1096-42-124 **Youngmi Hur*** (hur@jhu.edu), **Hyungju Park** and **Fang Zheng**. *Multi-D Wavelet FB Design using Quillen-Suslin Theorem for Laurent Polynomials.*

In this talk we present a new approach for constructing the wavelet filter bank. Our approach enables constructing nonseparable multidimensional non-redundant wavelet filter banks using the Quillen-Suslin Theorem for Laurent polynomials. Our construction method presents some advantages over the traditional methods of multidimensional wavelet filter bank design. First, it works for any spatial dimension and for any sampling matrix. Second, it does not require the initial lowpass filters to satisfy any additional assumption such as interpolatory condition. Third, it provides an algorithm for constructing a wavelet filter bank from a single lowpass filter so that its vanishing moments are at least as many as the accuracy number of the lowpass filter. (Received August 01, 2013)

1096-42-178 **Yi Hu***, Department of Mathematical Sciences, Georgia Southern University, Statesboro, GA 30460, and **Xiaochun Li**, Department of Mathematics, University of Illinois at Urbana-Champaign, Urbana, IL 61801. *Discrete Fourier restriction associated with Schrödinger equations.*

The standard way of solving nonlinear Schrödinger equations (NLS) is to rewrite the differential equations into the equivalent form of integral equations, and then apply Picard iteration. In this process the Strichartz estimate is usually used to control the nonlinear term. When we consider the periodic NLS, however, the exact periodic analogue of the continuous Strichartz estimate fails, so it forces us to find some new inequalities of the same type. The periodic Strichartz estimate is also equivalent to the discrete Fourier restriction estimate. The results for this type of restriction as well as some other related topics will be presented. (Received August 13, 2013)

1096-42-180 **Jodi Herbert***, Kansas State University, Department of Mathematics, 138 Cardwell Hall, Manhattan, KS 66506, and **Virginia Naibo**. *Bilinear pseudodifferential operators with symbols in Besov spaces.* Preliminary report.

The boundedness of bilinear pseudodifferential operators on Lebesgue spaces is demonstrated in the case when the corresponding symbols belong to various Besov spaces of product type. Also shown is the connection between these results and their counterparts for symbols in certain bilinear Hörmander classes. Finally, as a direct consequence of the outcomes in the context of Besov spaces, an upper bound on the number of derivatives sufficient for boundedness is obtained. (Received August 13, 2013)

1096-42-543 **Jacqueline Davis*** (jacqueline.t.davis@vanderbilt.edu). *Spatio-temporal sampling schemes in evolutionary systems.*

When an evolving signal is to be reconstructed from samples of it, can fine time sampling conpensate for coarse spatial sampling? This poster explores this question, which is called the dynamical sampling problem. Under some conditions, the answer is "yes" - it is possible to exactly reconstruct a signal from coarse spatial samples taken at many times. Knowledge of the evolutionary nature of the system is exploited to allow full recovery of spatially undersampled signals.

Mathematically, the problem is stated as follows. Let x_0 be a signal and A_t be an evolution rule so that the signal at time $t > 0$ is given by $x_t = A_t x_{t-1}$, and let S_t be a subsampling operator so that the measured signal at time t is given by $S_t x_t$. Under what conditions on x_0, A_t, and S_t, can x_0 be recovered from the set of samples $\{S_{t_i} x_{t_i}\}_I$, where I is a finite set? (Received September 05, 2013)

1096-42-978 **Chang-Pao Chen*** (cpchen@wmail.hcu.edu.tw), Center for General Education, Hsuan Chuang University, Hsinchu, 30092, Taiwan, and **Elijah Liflyand** (liflyand@gmail.com), Department of Mathematics, Bar-Ilan University, 52900 Ramat-Gan, Israel. *Almost everywhere convergence of Fourier integrals revisted.*

This is a report from our joint work published in Arch. Math. 100(2013), 587-592. In the mentioned article, we presented a condition of proved worth, which guarantees almost everywhere convergence of Fourier integrals of functions from an essentially wider class than known earlier. In particular, the almost everywhere convergence of the spherical partial sums is deduced. (Received September 11, 2013)

1096-42-1006 **John J Benedetto*** (jjb@math.umd.edu), Norbert Wiener Center, Department of Mathematics, University of Maryland, College Park, MD 20742, and **Wojciech Czaja**, Norbert Wiener Center, Department of Mathematics, University of Maryland, College Park, MD 20742. *Multiplicative frames for dimension reduction in reactive sensing.* Preliminary report.

Laplacian eigenmaps and other non-linear kernel eigenmap methods are described for their role in obtaining effective dimension reduction of multi-spectral data. Their use in classification problems is constrained since different classes that should be identified are not necessarily orthogonal. This leads to the introduction of the theory of frames and the concept of frame potential energy as a natural paradigm for analyzing a host of classification problems in the setting of kernel eigenmap methods. (Received September 12, 2013)

1096-42-1089 **Oleksandra V Beznosova*** (alexbeznosova@yahoo.com), **Maria Cristina Pereyra** and **Jean Carlo Moraes**. *Sharp Bounds for t-Haar Multipliers in L_2.*

We obtain sharp estimates on the L_2 norms of the general t-Haar multiplier of complexity (m,n) operators for any real t with polynomial dependence on the complexity. t-Haar multipliers naturally appear in the study of Sobolev spaces on Lipschitz curves and are closely related to the resolvent of the dyadic paraproduct. (Received September 12, 2013)

1096-42-1322 **Naoki Saito*** (saito@math.ucdavis.edu), Department of Mathematics, University of California, Davis, CA 95616, and **Jeff L. Irion**. *The Hierarchical Graph Laplacian Eigen Transform (HGLET) and Its Relatives for Data Analysis on Graphs and Networks.*

The Hierarchical Graph Laplacian Eigen Transform (HGLET) is our new analysis tool for data measured on vertices of a given graph. It starts with computing the graph Laplacian eigenvectors of the whole graph. Then, using the Fiedler vector (i.e., the eigenvector corresponding to the second smallest eigenvalue), we partition the graph into two subgraphs. In each subgraph, we compute its own graph Laplacian eigenvectors, and we repeat this process recursively until each subgraph has a single vertex. This tree-structured set of eigenvectors contains a redundant set of orthonormal bases and allows us to extract the most suitable orthonormal basis for the task at hand (e.g., denoising) using the best-basis type algorithm. We will also describe two variants of the HGLET: the Haar-like HGLET and its smoother version called the Orthonormalized Hierarchical Fiedler Transform (OHFT). Both use only the Fiedler vector of each subgraph. The former binarizes each Fiedler vector according to its sign under the constraint of being orthogonal to the constant-valued vector while the latter applies the orthogonalization procedure to the computed Fiedler vector after each partition against all those previously computed. We will demonstrate their usefulness for various applications. (Received September 14, 2013)

1096-42-1403 **Michael Goldberg*** (goldbeml@ucmail.uc.edu), Department of Mathematical Sciences, University of Cincinnati, French Hall - West, Cincinnati, OH 45221-0025. *Bochner-Riesz estimates for functions with vanishing Fourier transform.* Preliminary report.

The Bochner-Riesz multipliers are characterized by a nonsmooth transition at the unit sphere, therefore one can expect better behavior when they are applied to functions whose Fourier transform vanishes on the unit sphere. We prove a range of improved $L^p \to L^q$ estimates in $\mathbf{R}^n$, $n \geq 2$, for Bochner-Riesz multipliers acting on such functions. The problem arises naturally in applications including the uniqueness of solutions to the Helmholtz equation, or the absence of embedded resonances for Schrödinger operators with potentials in $L^r(\mathbf{R}^n)$. (Received September 15, 2013)

1096-42-1562 **Betsy Stovall*** (stovall@math.wisc.edu). *Uniform estimates for Fourier restriction to polynomial curves in $\mathbb{R}^d$.*

We prove uniform $L^p \to L^q$ bounds for Fourier restriction to polynomial curves with affine arclength measure, in the full conjectured range. (Received September 16, 2013)

1096-42-1799 **Roza Aceska*** (roza.aceska@vanderbilt.edu), **Akram Aldroubi** (akram.aldroubi@vanderbilt.edu) and **Sui Tang** (sui.tang@vanderbilt.edu). *Dynamical sampling in hybrid shift invariant spaces.* Preliminary report.

In sampling and reconstruction problems of a time-varying field it is more reasonable to work with hybrid shift-invariant spaces (HSIS). The localized nature of these spaces allows for choosing locally adapted building blocks and sampling rates. We explore the properties of these spaces. Then we generalize the technique of dynamical sampling in shift-invariant spaces to HSIS and explore the possibility of sub-sampling with a spatially adaptive sampling rate. (Received September 16, 2013)

1096-42-1819 **Roza Aceska**, **Akram Aldroubi** and **Sui Tang*** (sui.tang@vanderbilt.edu). *Overcoming singularity of signal recovery by dynamical sampling in hybrid shift invariant spaces.*

We formulate the dynamical sampling problem in hybrid shift invariant spaces. We derive the necessary and sufficient conditions for an invertible dynamical sampling operator and discuss the stability of reconstruction. Whenever the dynamical sampling operator is singular, we show that it is possible to recover the signal by taking extra samples. (Received September 17, 2013)

43 ► Abstract harmonic analysis

1096-43-905 **Peter G. Casazza*** (casazzap@missouri.edu), 116 Math Sciences Building, Columbia, MO 65211-1400, **Jameson Cahill** (jcahill@math.duke.edu), Mathematics Department, Durham, NC 27708, **Jesse Peterson** (dustin.mixon@gmail.com), Department of Mathematics and Statistics, Wright-Patterson Air Force Base, Dayton, OH 45433, and **Lindsey M. Woodland** (lmwvh4@mail.missouri.edu), Department of Mathematics, Columbia, MO 65211-1400. *Phase Retrieval By Projections.*

Phaseless reconstruction has broad application to x-ray crystallography, electron microscopy, diffractive imaging, x-ray tomography and more. The mathematics of phase retrieval is a very active area of research at this time. Recently, in several areas of application - such as crystal twinning - it has become necessary to do phaseless reconstruction from the norms of projections onto subspaces of a Hilbert space. It was believed that norms of projections give much less information than rank one projections and so we would need many more projections to do phaseless than we can do with vectors. We will look at recent results on this problem which include the surprising results that we can do phaseless reconstruction with the same number of arbitrary rank projections as we can do it with vectors. This now reverses the above problem to: Is it possible to do phaseless with fewer projections than we can do with vectors? (Received September 11, 2013)

1096-43-1462 **Alexander Cloninger** and **Wojciech Czaja***, Department of Mathematics, University of Maryland, College Park, MD 20742, and **Timothy Doster**. *The Preimage Problem for Laplacian Eigenmaps.* Preliminary report.

Nonlinear dimensionality reduction has become an important part of machine learning and harmonic analysis, due to the influx of big data in many applications. For many techniques, such as, e.g., Laplacian Eigenmaps, this leads to analysis in a new feature space, which is the target space of the dimension reduction process. On the one hand, such space may be very useful for direct comparison of heterogeneous sensing modalities. On the other hand, however, its non-physical nature may cause difficulties in certain applications. Hence, our goal in this talk is to present an algorithm for fast, approximate inversion of Laplacian Eigenmaps. In our construction we rely on Nystroem extension principle, L1 regularization, and multidimensional scaling. We shall illustrate the usefulness of our algorithm in such applications as heterogeneous data fusion or image inpainting. (Received September 15, 2013)

1096-43-1469 **John J. Benedetto** and **Wojciech Czaja***, Department of Mathematics, University of Maryland, College Park, MD 20742, and **Timothy Doster** and **Martin Ehler**. *Fusion of spatial and spectral features in hyperspectral imagery.* Preliminary report.

As new remote sensing modalities emerge, it becomes increasingly important to find novel algorithms for fusion and integration of different data types for the purposes of target/anomaly detection or classification. In this presentation, we provide an overview of several new approaches to the spatial-spectral fusion problem in hyperspectral imagery. This problem emerges when classical spectral analysis is enriched by a detailed study of spatial distribution of features. The approaches we shall describe are rooted in harmonic analysis, and are based on creating novel fused representations of the spatial-spectral data, which are then subject to analysis by means of the state-of-the-art classifiers. Our approaches involve machine learning techniques based on analysis of joint data-dependent graphs and the resulting data-dependent fusion operators and their representations, as well as wavelet packet representations and nonlinear tresholding. (Received September 15, 2013)

1096-43-2606 **Alexander Cloninger** and **Wojciech Czaja***, Department of Mathematics, University of Maryland, College Park, MD 20742, and **Timothy Doster**. *Operator-based Data Fusion.* Preliminary report.

Integration and fusion are among the longstanding objectives of data analysis. This problem may be formulated as a question about finding a suitable feature space in which different modes of information can be jointly embedded. The goal is to improve the outcome of analysis of this jointly embedded data, as compared to inferences made from individual sources. This is often possible due to complementarity of information contained in the separate modalities.

In our talk we shall present a deterministic approach to data fusion, which exploits fused representations of certain well known data-dependent operators. A classical example of such an operator is the data-dependent graph Laplacian. Through its eigendecomposition we introduce a novel notion of heterogeneous data fusion, which allows us to combine different graph structures arising from individual modalities, into one joint representation.

Our theory then can be applied to problems which include spatial-spectral fusion, or fusion of hyperspectral satellite imagery (HSI) with LIDAR data. We verify the results of our methods by utilizing them for the HSI classification problem. (Received September 17, 2013)

44 ► Integral transforms, operational calculus

1096-44-262 **Taryn C Flock*** (taryn.flock@berkeley.edu). *Uniqueness of extremizers for an endpoint inequality of the k-plane transform.*

The Radon transform is an integral transform with applications in mathematics, tomography, and medicine. We discuss the Radon transform, the X-ray transform and their generalization: the k-plane transform. When $k = n - 1$, the k-plane transform coincides with the Radon transform; when $k = 1$, the X-ray transform.

The k-plane transform is a bounded operator from $L^p(\mathbb{R}^n)$ to L^q of the Grassmann manifold of all affine k-planes in R^n for certain exponents p and q that depend on k and n. In the endpoint case $q = n+1$, we identify all extremizers of the associated inequality for the general k-plane transform. (Received August 25, 2013)

1096-44-2038 **Zsolt Patakfalvi*** (pzs@princeton.edu) and **Karl Schwede**. *Depth of modules at non sharply F-pure centers and base-change for the relative canonical sheaf.*

I will present a depth inequality for sharply F-pure pairs at non sharply F-pure centers. A special case is: if (X, D) is a sharply F-pure pair and x is a point of X that is not a sharply F-pure center, then for any n such that nD is integral, the divisiorial sheaf $\mathcal{O}_X(-nD)$ has depth at least as big as the minimum of the codimension of x in X and 3 (i.e. it satisfies the requirements for S_3 at x). I will also explain how this condition guarantees that the relative canonical sheaf is compatible with base-change in flat families of sharply F-pure varieties, an important consequence for the construction of moduli spaces of higher dimensional varieties in positive characteristics. (Received September 17, 2013)

45 ► Integral equations

1096-45-407 **Nar S Rawal*** (nsr0005@auburn.edu), Department of Mathematics and Statistics, Auburn University, Auburn, AL 36849, and **Wenxian Shen**. *Criteria for the Existence of Principal Eigenvalue of Time Periodic Nonlocal Dispersal Operators and Its Applications.*

Both random dispersal operators and nonlocal dispersal operators have been used extensively to model diffusive system in applied sciences and mathematics. While much is known about the existence of principal eigenvalue (PEV) of random dispersal operators, little is known about the existence of PEV of time periodic nonlocal dispersal operators. It should be pointed out that PEV theory of nonlocal dispersal operators without time dependence have been already studied. The talk will be focussed on the criteria for the existance of PEV of time periodic nonlocal dispersal operators with Dirichlet type, Neumann type, and periodic type boundary conditions. In addition to the existence of PEV, the talk will also be focussed on the application of the established PEV theory to the existence,uniqueness, and stability of time periodic positive solutions to Fisher or KPP type equations with nonlocal dispersal in periodic media. (Received September 02, 2013)

1096-45-2255 **Emmanuel J. Morales Butler*** (ejmorale@asu.edu), Mathematical, Computational & Modeling, Sciences Center, Arizona State University, Physical Sciences, A-Wing, Tempe, AZ 85287-1904, and **Juan P. Aparicio** (juan.p.aparicio@gmail.com) and **Carlos Castillo-Chavez** (ccchavez@asu.edu). *A Global Uncertainty and Sensitivity Analysis on a Simple Age-of-Infection SIR Model.* Preliminary report.

Simple epidemiological models are frequently used to estimate the effect of different control strategies on epidemics dynamics. In some cases effect of parameter uncertainty is quantified via uncertainty analysis on model output variables like the basic reproduction number or the final epidemic size. However a more general question is how these quantities depend on model assumptions. Here we consider the effect of the assumed distribution for the infectious period on the output variables. In this work we modeled the infectious period using the family gamma distribution which include as limiting cases the exponential and the delta distributions. In this work a global uncertainty and sensitivity analysis is applied to a simple age-of-infection Susceptible-Infectious-Recovered model described by a nonlinear system of Volterra integral equations. Results reflect that the variance of the infectious period distribution is a key input modeling parameter in the prediction precision of three out of five output variables considered. The novel application in this work serves as a research decision tool that determines which type of a nonlinear system is more suitable to utilize: if a model governed by Volterra integral equations or ordinary differential equations. (Received September 17, 2013)

1096-45-2328 **Yousef Al-Jarrah*** (aljar1ya@cmich.edu), 1535 E Bellows st, Apt D, Mount Pleasant, MI 48858. *A Wavelet Based Method for the Solution of Integral Equations.*

we use scaling function interpolation method to solve linear integral equations, and we prove a convergence theorem for the solution of integral equations. We present two examples which have better results than others
(Received September 17, 2013)

46 ► Functional analysis

1096-46-34 **Weihua Li*** (wli@colum.edu), 600 S. Michigan Ave., Science & Mathematics, Columbia College Chicago, Chicago, IL 60605, and **Stefanos Orfanos**. *Crossed products and MF algebras.*

We prove that the crossed product $\mathcal{A} \rtimes_\alpha G$ of a unital finitely generated MF algebra $\mathcal{A}$ by a discrete finitely generated amenable residually finite group G is an MF algebra, provided that the action α is almost periodic. We also construct two examples of crossed product C^*-algebras whose BDF Ext semigroups are not groups.
(Received September 04, 2013)

1096-46-277 **Robert S. Strichartz*** (str@math.cornell.edu), Math Dept., Malott Hall, Cornell Univ., Ithaca, NY 14853. *"Graph Paper" Trace Characterizations of Functions of Finite Energy.*

We characterize functions of finite energy in the plane in terms of traces on the lines that make up "graph paper" with squares of side length m^n, for all integers n, and certain 1/2-order Sobolev norms of the graph paper lines. We also obtain analogous results for functions of finite energy on two classical fractals: the Sierpinski gasket and the Sierpinski carpet. (Received August 26, 2013)

1096-46-322 **Sofia Ortega Castillo*** (ortega@math.tamu.edu), Department of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77843, and **William B. Johnson** (johnson@math.tamu.edu), Department of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77843. *Corona and cluster value problem in infinite-dimensional spaces.*

We will present background on the corona and cluster value problems in finite-dimensional spaces, paying special attention to the ball and the polidisk of the Euclidean space. After introducing an overview of some basic theory of Complex Analysis on Banach spaces, we will also talk about the cluster value problem in infinite-dimensional spaces, mentioning cluster value theorems for c_0 and Hilbert space, which are infinite-dimensional analogues of the polidisk and the ball of the Euclidean space. We will also mention some cluster value theorems for ℓ_p, $1 \leq p < \infty$, for uniformly convex spaces and for $C(K)$ spaces, with K compact, Hausdorff and dispersed. We will also discuss a reduction of the cluster value problem in any Banach space to ℓ_1 sums of finite-dimensional spaces. (Received August 28, 2013)

1096-46-496 **Paul S Muhly** and **Baruch Solel*** (mabaruch@tx.technion.ac.il), Department of mathematics, Technion, Israel institute of Technology, 32000 Haifa, Israel. *Matricial Families and Weighted Shifts.*

Let A be the Hardy algebra of a W^*-correspondence E over a W^*-algebra M. Each $F \in A$ defines a family of operator-valued functions $\widehat{F}_\sigma$ indexed by the normal representations of M. Each function is defined on the open unit ball of the correspondence $E^{\sigma *}$. Such a family exhibits "matricial structure" that is a central focus of this session.

I will show how to use operator-valued weighted shifts to generate and study matricial families of operator-valued functions defined on more general matricial sets that are not necessarily unit balls. This work generalizes some results of Popescu. (Received September 04, 2013)

1096-46-516 **Clifford A Bearden**, **David P Blecher** and **Sonia Sharma*** (sonia.sharma@cortland.edu). *Some Remarks on Positivity in Operator Algebras.* Preliminary report.

In recent papers David Blecher and Charles Read have introduced and studied a new notion of positivity for operator algebras with an eye to extending certain C*-algebraic results and theories to more general algebras. We present complements to some facts in the just mentioned papers, concerning this notion of positivity. (Received September 05, 2013)

1096-46-603 **Pinhas Grossman**, **Masaki Izumi** and **Noah Snyder***, nsnyder@math.indiana.edu. *The Brauer-Picard groupoid of the Asaeda-Haagerup subfactor.* Preliminary report.

The classification of small index subfactors yielded several new subfactors, which are now beginning to be understood. The Asaeda-Haagerup small index subfactor gives a Morita equivalence between two fusion categories. We determine all fusion categories in this Morita equivalence class (there are exactly 6) and all Morita equivalences between them. In particular, we give a new "symmetric" construction of the Asaeda-Haagerup subfactor. This construction allows for new computations (for example, of the Drinfel'd center of the Asaeda-Haagerup fusion categories) and suggests that Asaeda-Haagerup might live in an infinite family. Furthermore, we identify the Brauer-Picard 3-groupoid of Asaeda-Haagerup and construct a new extension of the Asaeda-Haagerup fusion categories by the Klein 4-group. (Received September 07, 2013)

1096-46-606 **Dongyang Chen** and **Bentuo Zheng*** (bzheng@memphis.edu), Department of Mathematical Sciences, University of Memphis, Memphis, TN 38152. *Lipschitz p-nuclear operators from a finite metric space into a Banach space.*

Let T be a Lipschitz mapping from a finite metric space X into a Banach space Y. We show that the Lipschitz p-nuclear norm and the Lipschitz p-integral norm of T coincide. Moreover, we give an upper estimate of the Lipschitz p-nuclear norm of T in terms of the cardinality of X and the Lipschitz norm of T. A different upper estimate of the Lipshcitz p-nuclear norm of T is obtained when Y is 2-uniformly convex. (Received September 07, 2013)

1096-46-642 **Anthony R Weston*** (westona@canisius.edu), 2001 Main Street, Buffalo, NY 14208. *Negative type properties of finite ultrametric spaces.* Preliminary report.

Ultrametric spaces have special negative type properties. For instance, they are the only metric spaces that have p-negative type for all $p > 0$. In this talk I will discuss the "enhanced" p-negative type inequalities of finite ultrametric spaces in the limit as p tends to ∞. The notion of enhanced negative type provides a quantification of the "strictness" of non-trivial negative type inequalities. This is a preliminary report of joint work undertaken with Ian Doust and Stephen Sánchez at the University of New South Wales, Australia. (Received September 08, 2013)

1096-46-694 **Yingfan Liu** and **Qinghong Zhang*** (qzhang@nmu.edu), Dept. of Mathematics and Computer Scienc, Northern Michigan University, Marquette, MI 49855. *The Rogalski-Cornet-type Surjectivity Theorem without Continuity Assumptions.*

In this talk, we present a Rogalski-Cornet-type surjectivity theorem without any continuity assumptions. Some stability results for certain set-valued maps based on this result are also discussed. We provide an example to show that the set of conditions for this Rogalski-Cornet-type surjectivity theorem is weaker than that for the classical Rogalski-Cornet theorem. (Received September 09, 2013)

1096-46-906 **Jonathan Novak*** (jnovak@math.mit.edu), 77 Massachusetts Avenue, Cambridge, MA 02139. *Asymptotics of looped cumulant lattices.* Preliminary report.

A looped cumulant lattice is an array of multilinear functionals defined on an algebra of noncommutative polynomials. The characteristic property of looped cumulant lattices is that they are governed by a hierarchy of noncommutative partial differential equations known as the loop equations. This hierarchy can be solved recursively, allowing a complete determination of the asymptotics of LCLs. On one hand, LCLs arise as the correlation functions of several interacting random matrices, and on the other they are related to freeness and its higher-order generalizations. Therefore, LCLs constitute a very natural bridge between random matrices and free probability. This talk is based on joint work with Alice Guionnet. (Received September 11, 2013)

1096-46-907 **Ionel Popescu***, Georgia institute of Technology, School of Mathematics, 686 Cherry Street, Atlanta, GA 30332, and **Christian Houdre**. *Refinements of the Free Poincare Inequality.*

The free Poincare inequality, at least in one dimension, has a similar flavor to the classical one, though there are some differences. In this talk I will extend it in two direction. One is in the sense of Brascamp-Lieb and the other direction which is applicable to the semicircular law and it's the parallel of a classical result due to Houdre and others.

This is joint work with Christian Houdre. (Received September 11, 2013)

1096-46-977 **S J Dilworth*** (dilworth@math.sc.edu) and **B Randrianantoanina**. *Almost transitive and maximal norms in classical Banach spaces.* Preliminary report.

We prove that the spaces ℓ_p, $1 < p < \infty, p \neq 2$, and all their infinite-dimensional subspaces do not admit equivalent almost transitive renormings. This answers a problem posed by Deville, Godefroy and Zizler in 1993. We obtain this as a consequence of a new property of almost transitive spaces with a Schauder basis, namely we prove that in such spaces the unit vector basis of ℓ_2^2 belongs to the two-dimensional asymptotic structure and we obtain some information about the asymptotic structure in higher dimensions.

We also prove that the spaces ℓ_p, $1 < p < \infty$, $p \neq 2$, have continuum different renormings with 1-unconditional bases each with a different maximal isometry group, and that every 1-symmetric space other than ℓ_2 has at least a countable number of such renormings. On the other hand we show that the spaces ℓ_p, $1 < p < \infty$, $p \neq 2$, have continuum different renormings each with an isometry group which is not contained in any maximal isometry group of a renorming of ℓ_p. This answers a question of Wood. (Received September 11, 2013)

1096-46-1002 **Alan D Wiggins*** (adwiggin@umich.edu), Department of Mathematics & Statistics, 2014 CASL Building, 4901 Evergreen Road, Dearborn, MI 48128. *Perturbation Problems for Subfactors.* Preliminary report.

Given two factors M and N (either of type II_1 or type III) acting on the same Hilbert space, we examine the subfactor invariants that can be preserved when the distance $d(M,N)$ in the Hausdorff metric is sufficiently small. (Received September 12, 2013)

1096-46-1060 **Noel Ramsey DeJarnette***, Department of Mathematics, University of Illinois, 1409 West Green Street, Urbana, IL 61801. *Orlicz spaces, Lorentz spaces, and self-improving Orlicz-Poincaré inequalities: Connections and consequences.*

The theory of Lorentz spaces and Orlicz-Sobolev spaces hint that the algebraic scale of exponents is too coarse to capture the critical transition between changes in fundamental properties in many contexts. In this talk, we introduce the Young function used to define the Lorentz-Zygmund class and explore the major appearances of a condition on the logarithmic scale, optimal embedding and the association or Orlicz gauges to Lorentz spaces, and show that this condition also appears in the context of self-improving Orlicz-Poincaré inequalities. We provide an example of a planar set that shows the logarithmic scale is the correct "fineness" for self-improvement of Orlicz-Poincaré inequalities. (Received September 12, 2013)

1096-46-1064 **Alice Guionnet** and **Dimitri Shlyakhtenko*** (shlyakht@math.ucla.edu). *Free Monotone Transport.*

We show that monotone optimal transport maps between certain unitarily invariant measures on spaces of n-tuples of $N \times N$ matrices converge in the large-N limit to a map given by analytic functional calculus. The limit map can be interpreted as a free monotone transport map in the sense of free probability theory. We discuss some consequences, including applications to operator algebras. (Received September 12, 2013)

1096-46-1081 **Bogdan Teodor Udrea*** (budrea@illinois.edu), 1409 W. Green Street, Urbana, IL 61801, and **Ionut Chifan** and **Thomas Sinclair**. *Inner amenability for groups and central sequences in factors.*

We show that a large class of i.c.c., countable, discrete groups satisfying a weak negative curvature condition are not inner amenable. By recent work of Hull and Osin, our result recovers that mapping class groups and $Out(F_n)$ are not inner amenable. We also show that the group-measure space constructions associated to free, strongly ergodic p.m.p. actions of such groups do not have property Gamma of Murray and von Neumann. This is joint work with Ionut Chifan and Thomas Sinclair. (Received September 12, 2013)

1096-46-1121 **Paul S. Muhly*** (paul-muhly@uiowa.edu), Department of Mathematics, University of Iowa, Iowa City, IA 52242, and **Baruch Solel** (mabaruch@tx.technion.ac.il), Technion, 32000 Haifa, Israel. *A Case for the Trace in Free Analysis.* Preliminary report.

Noncommutative function theory involves, inter alia, completions of algebras of generic matrices. In this talk we will discuss what the corresponding trace algebras can contribute to the subject. (Received September 13, 2013)

1096-46-1224 **Sean Li*** (seanli@math.uchicago.edu). *Coarse differentiation of Lipschitz functions.*

We review a notion of large-scale differentiation for Lipschitz maps between Banach spaces. We then discuss recent extensions of this phenomenon to the nonabelian setting of Carnot groups. (Received September 13, 2013)

1096-46-1301 **Alexander A Katz*** (katza@stjohns.edu), St. John's University, SJC of LAS, Dep. of Math & CS, 8000 Utopia Parkway, SJH-334-i, Queens, NY 11439. *On Pedersen-Takahasi Theorem for locally C*-algebras.*

Pedersen and Takahasi have obtained the following characterization of an order-related subalgebra in a C*-algebra A: B is an order-related subalgebra of A if and only if each positive linear functional on B has a unique norm-preserving extension to A. We extend this result to obtain an analogous characterization of order-related subalgebras in locally C*-algebras. (Received September 14, 2013)

1096-46-1335 **Joseph Newhall*** (joseph.newhall@zu.ac.ae) and **Robert K. Goodrich**. *On the Density of Henig Efficeint Points in Locally Convex Topological Vector Spaces.*

This paper presents a generalization of the Arrow, Barankin and Blackwell theorem to locally convex Hausdorff topological vector spaces. Our main result relaxes the requirement that the objective set A is compact; we show asymptotic compactness is sufficient provided the asymptotic cone of A can be separated from the ordering cone, C, by a closed, convex cone. We introduce this notion as the Cone Separation Property and show that in normed spaces it is equivalent to $A_\infty \cap C = \{0\}$. In this way, our main result generalizes a theorem of A. Göpfert , C. Tammer and C. Zălinescu to locally convex spaces. We also generalize a well known result about expansion cones to locally convex spaces. (Received September 15, 2013)

1096-46-1376 **Michael Brannan*** (mbrannan@illinois.edu) and **Zhong-Jin Ruan** (ruan@illinois.edu). *L_p-representations of free quantum groups.*

I will report on recent joint work with Zhong-Jin Ruan, where we investigate the structure of L_p-representations of unimodular discrete quantum groups. Roughly speaking, these are unitary representations with the property that there exists an orthonormal basis of the Hilbert space such that the corresponding matrix coefficients of the representation live in the non-commutative L_p-space associated to the Haar weight. For certain examples of free quantum groups, we characterize (for all $p \in [1, \infty]$) the positive definite functions associated to L_p-representations. As an application of this characterization, we show that the Hopf-$*$-algebra of polynomial functions over a free orthogonal quantum group admits uncountably many pairwise non-isomorphic "exotic" completions as a quantum group C*-algebra. (Received September 15, 2013)

1096-46-1381 **William B. Johnson*** (johnson@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77845-3368. *Embeddings of $\ell_p(\aleph)$ into L_p spaces.* Preliminary report.

Gideon Schechtman and I prove that if X is a subspace of an L_p space, $1 < p < 2$, and $\ell_p(\aleph_1)$ does not embed into X, then X embeds into $L_p(\mu)$ for some finite measure μ. We also give appropriate versions of this result for $\ell_p(\aleph)$ with $\aleph$ any uncountable cardinal. The $\aleph_1$ result complements a theorem proved by P. Enflo and H. P. Rosenthal 40 years ago; namely, that $\ell_p(\aleph_1)$, $1 < p < 2$, does not (isomorphically) embed into $L_p(\mu)$ with μ a finite measure.

This work is an outgrowth of an unsuccessful attempt to solve a problem left open by Enflo and Rosenthal; namely, whether $L_p(\mu)$ can have an unconditional basis when $1 < p \neq 2 < \infty$, the measure μ is finite, and the density character of $L_p(\mu)$ is $\aleph_1$. If the answer is yes, then the results of Enflo and Rosenthal would show that "$L_p(\{-1,1\})^{2^{\aleph_0}})$ has an unconditional basis" is undecidable. (Received September 15, 2013)

1096-46-1588 **Florent P. Baudier*** (florent@math.tamu.edu), College Station, TX. *Geometry of layers of cubes: applications in geometric group theory and nonlinear geometry of Banach spaces.*

One can equip the set of all finite subsets of the integers with the symmetric difference metric, i.e. the distance between two finite subsets is the cardinality of their symmetric difference. This metric space, which is isometric to the infinite Hamming cube, and its relatives turn out to be related to important geometric properties of Banach spaces. In this talk, we will give two utilizations of those metrics. The first application is related to fundamental questions in geometric group theory. We will show how a tight estimate on the Lebesgue compression (introduced by Guentner and Kaminker) of ℓ_p-spaces can be derived from a beautiful stabilization result of Kalton and Randrianarivony. The second application occurs in nonlinear geometry of Banach spaces. Given a compact metric space K one shall establish a link between the Cantor-Bendixson index of K and the $\mathcal{C}(K)$-distortion of the set of subsets of the integers with at most k elements equipped with the symmetric difference metric, denoted $\Delta_{\leq k}$. Estimates on the $\mathcal{C}(K)$-distortion of the spaces $\Delta_{\leq k}$ will be given as well.

The work presented covers joint work with F. Albiac and joint work with D. Freeman, T. Schlumprecht and A. Zsak. (Received September 16, 2013)

1096-46-1607 **Nate Brown*** (nbrown@math.psu.edu), Dept. of Mathematics, Penn State University, State College, PA 16802. *The structure of simple operator algebras.* Preliminary report.

I will discuss some of the striking parallels that have recently emerged in the structure theory of simple W*- and C*-algebras. (Received September 16, 2013)

1096-46-1633 **Kelly Bickel*** (kbickel3@math.gatech.edu) and **Greg Knese**. *Two-Variable Transfer Function Realizations and Agler Kernels.*

Every Schur function on the bidisk can be decomposed into a sum of positive kernels, called Agler kernels. These positive kernels induce important representation formulas for bounded holomorphic functions, called transfer function realizations (T.F.R.'s), in terms of Hilbert spaces contractions. Alger's proof of the existence of these kernel decompositions and T.F.R.'s was nonconstructive and their structure was quite mysterious for many years.

In previous work, the speaker and Greg Knese constructed Agler kernels for inner functions, examined the structure of such kernels, and obtained refined results for rational inner functions. In this talk, we will discuss extensions of these constructions and results to general two-variable Schur functions. We will also highlight new, related results about the structure of two-variable T.F.R.'s. This is joint work with Greg Knese. (Received September 16, 2013)

1096-46-1704 **Danny Wray Crytser***, danny@math.dartmouth.edu. *Continuous-trace graph C^*-algebras.* Preliminary report.

A theorem of Muhly, Renault, and Williams give necessary and sufficient conditions for the C^*-algebra of a locally compact, second countable, Hausdorff groupoid with abelian stabililzers and Haar system to have continuous trace. As the Cuntz-Krieger graph algebras of row-finite graphs without sources are isomorphic to the C^*-algebras of naturally defined path groupoids, we seek to translate the groupoid conditions of their theorem to conditions on such a graph which ensure that the associated C^*-algebra has continuous trace. A result of Goehle characterizes those graphs which possess Hausdorff spectrum, and we use this characterization along with two finiteness notions for graphs, path-finiteness and finite ancestry, to characterize the graphs that have continuous-trace C^*-algebras. (Received September 16, 2013)

1096-46-1715 **J. Alejandro Chavez-Dominguez***, 2515 Speedway Stop C1200, Austin, TX 78712-1202. *Lipschitz p-convex and q-concave maps.*

The notions of p-convexity and q-concavity are mostly known because of their importance as a tool in the study of isomorphic properties of Banach lattices, but they also play a role in several results involving linear maps between Banach spaces and Banach lattices. In this talk we introduce Lipschitz versions of these concepts, dealing with maps between metric spaces and Banach lattices, and prove nonlinear versions of two well-known factorization theorems (due to Maurey/Nikishin and Lindenstrauss/Tzafriri). We also show an explicit relationship between the linear and nonlinear versions of p-convexity. (Received September 16, 2013)

1096-46-1768 **Yoann Dabrowski**, **Ken Dykema*** (kjd@tamu.edu), **Claus Koestler**, **Kunal Mukjherjee** and **John D. Williams**. *Choquet simplices of quantum symmetric states.*

In anology with Köstler and Speicher's noncommutative de Finetti theorem, the quantum symmetric states on the universal free product of a C*-algebra with itself infinitely many times can be characterized by freeness with amalgamation over the tail algebra (see Köstler's talk in this special session). Using a convenient characterization of the extreme quantum symmetric states, we show that the set of central quantum symmetric states is a Choquet simplex (in fact, a Bauer simplex) whose extreme points are the free product states. Also, the set of tracial quantum symmetric states is a Choquet simplex (and furthermore, a Poulsen simplex). (Received September 16, 2013)

1096-46-1769 **Stephen Avsec*** (savsec@math.tamu.edu), Department of Mathematics, Mailstop 3368, College Station, TX 77843-3368. *New Examples of Exchangeable Noncommutative Brownian Motion.*

We will begin by recalling the definition of noncommutative brownian motion due to B. Collins and M. Junge. We will then discuss several new constructions which can be used to produce new examples of such exchangeable brownian motions. These include a combinatorial approach due to M. Guta and an approach using operator-valued variables. This is joint work with Benoit Collins and Marius Junge. (Received September 16, 2013)

1096-46-1772 **Hari Bercovici***, bercovic@indiana.edu. *Approximate subordination and random matrices.*

The subordination functions appearing in the study of free convolutions have approximate analogues at the random matrix level. These approximations are used to study outlying eigenvalues of sums of random matrices which are invariant under unitary conjugation. This work (in progress) is joint with S. Belinschi, M. Fevrier, and M. Capitaine. (Received September 16, 2013)

1096-46-1779 **Ken Dykema*** (kjd@tamu.edu), **Fedor Sukochev** and **Dmitriy Zanin**. *Upper triangular forms for elements of finite von Neumann algebras.*

Using the Haagerup–Schultz hyperinvariant projections based on Brown measure, an arbitrary element T of a finite von von Neumann algebra $\mathcal{M}$ can be written in the form $T = N + Q$ where $N \in \mathcal{M}$ is normal and has the same Brown measure as T and where Q is s.o.t.-quasinilpotent. For h holomorphic in a neighborhood of the spectrum of T, we have $h(T) = h(N) + Q_h$, where Q_h is s.o.t.-quasinilpotent. (Received September 16, 2013)

1096-46-1833 **Swarup Narayan Ghosh*** (snghosh@bgsu.edu), 450 Mathematical Science Building, Bowling Green, OH 43403. *Proof of a conjecture of Andrew Gleason for uniform algebras on manifolds.* Preliminary report.

An important necessary condition for an uniform algebra A on a compact space X to be $C(X)$ (the collection of all complex-valued continuous functions on X) is that the maximal ideal space of A is X. Another such condition is that every point of X is a single (Gleason) part. In 1957, Andrew Gleason conjectured that together these two conditions are also sufficient. However, in 1968, Brian Cole constructed a counterexample to this conjecture. The failure of this conjecture gave rise to an interesting question: For which uniform algebras is this conjecture true? The answer of this question for some uniform algebras will be discussed in this talk. (Received September 16, 2013)

1096-46-1852 **Kenneth J Dykema** and **Claus Koestler*** (claus@ucc.ie), School of Mathematical Sciences, University College Cork, Western Gateway Building, Western Road, Cork, Ireland, and **John D Williams**. *Quantum symmetric states on free product C*-algebras.*

We introduce quantum symmetric states on the infinite universal free product of a C*-algebra with itself as a generalization of the notion of quantum exchangeable random variables. Extending and building on the noncommutative de Finetti theorem of Köstler and Speicher, we prove a de Finetti type theorem that characterizes quantum symmetric states in terms of amalgamated free products over the tail algebra. Furthermore we develop a convenient description of the set of all quantum symmetric states. In other words, our results provide in free probability the counterpart to Størmer's work on symmetric states of infinite tensor products of C*-algebras. The convex structure of this set of all quantum symmetric states can be further studied (see Dykema's consecutive talk in this special session). (Received September 16, 2013)

1096-46-1876 **Alexander Teplyaev*** (teplyaev@uconn.edu), **Michael Hinz** (mhinz@math.uni-bielefeld.de) and **Daniel Kelleher** (daniel.kelleher@uconn.edu). *Vector analysis for Dirichlet forms on fractals.*

We will discuss a possibility to define vector analysis for measurable Dirichlet forms (quadratic forms on scalar functions), with applications to the self-adjointness of the magnetic Laplacian and the Dirac operator (this construction combines ideas from classical and non-commutative functional analysis), and the existence of the intrinsic metrics. After that we will show how these ideas lead to the Hodge theorem and the existence and uniqueness for the Navier-Stokes equations for topologically one-dimensional spaces with strong local Dirichlet forms that can have arbitrary large Hausdorff and spectral dimensions. (Received September 16, 2013)

1096-46-1885 **Tatsuya Tate*** (tate@math.tohoku.ac.jp), Mathematical Institute, Tohoku University, 6-3, Aoba, Aramaki, Aoba-ku, Sendai, Miyagi 980-8578, Japan. *Asymptotics of one-dimensional quantum walks.*

Various local asymptotic formulas for transition probabilities of one-dimensional quantum walks with a constant quantum coin will be explained. The formulas heavily depend on the 'normalized position' of the walk. When the normalized position is inside the support of the weak-limit distribution (Konno distribution), an oscillating term appears in the leading term of the asymptotic formula. When the normalized position stays around the boundary of the support, the asymptotic formula is described in terms of the Airy function. In the outside the support, the transition probabilities decay exponentially. The rate function for the exponential decay rate will be explicitly given. (Received September 16, 2013)

1096-46-1897 **Injo Hur*** (ihur@math.ou.edu), dept. of math, university of Oklahoma, Nornam, OK 73069. *Ergodic Jacobi matrices and conformal maps.*

We study structural properties of the Lyapunov exponent γ and the density of states k for ergodic (or just invariant) Jacobi matrices in a general framework. In this analysis, a central role is played by the function $w = -\gamma + i\pi k$ as a conformal map between certain domains. This idea goes back to Marchenko and Ostrovskii, who used this device in their analysis of the periodic problem. (Received September 16, 2013)

1096-46-1931 **Bunyamin Sari***, Department of Mathematics, University of North Texas, 1155 Union Circle #311430, Denton, TX 76203-5017. *Uniform homeomorphisms of asymptotic-c_0 spaces.*

We prove that the upper envelope function of reflexive Banach spaces is an invariant under uniform homeomorphisms. In particular, a reflexive space that is uniformly homeomorphic to an asymptotic-c_0 space is asymptotic-c_0. (Received September 16, 2013)

1096-46-1970 **J William Helton***, 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 mostly done with Igor Klep, Scott McCullough, Chris Nelson and Jaka Cimpric At this point we have:

A. Free *-algebra versions of the classical real algebraic geometry description, ie. positivstellensatze (resp. nullstellensatze), which provide an algebraic certificate for a polynomial q to take positive definite (resp. zero) values on the set where another, q, takes positive definite (resp. zero) values;

B. Classifications of convex rational functions, varieties and open sets. There are shockingly few;

C. An emerging picture of free convex hulls and projections of free semi-algebraic sets;

D. Some theory of changes of variables to achieve non-commutative convexity and the relationship to positivstellensatze;

E. Other.

The work originates in trying to develop some theory for studying the matrix inequalities which are ubiquitous in linear engineering systems and control. The talk will select a topic from the list above and will be co-ordinated with Scott McCullough's talk. (Received September 16, 2013)

1096-46-2011 **Ben R Hayes*** (brh6@ucla.edu). *Extended von Neumann dimension for sofic groups and equivalence relations.*

We discuss how to extend the usual definition of von Neumann dimension for groups and measure-preserving equivalence relations to arbitrary Banach space representations of groups and equivalence relations, provided they are sofic. This goes by exploiting the analogy between the left regular representation of a group, and Bernoulli actions of this group, and employing methods in sofic entropy due to Lewis Bowen, David Kerr and Hanfeng Li. We discuss applications to Banach space representations of groups including partially answering a question due to Gromov, and potential applications to the study of measurable equivalence relations. (Received September 17, 2013)

1096-46-2045 **P. Brändén** and **M. Chasse*** (chasse@math.kth.se), Lindstedtsvägen 25, Mathematics Department, 100-44 Stockholm, Sweden. *Classifiaction theorems for operators preserving zeros in a strip.*

A characterization is given for linear operators which preserve the set of univariate complex polynomials whose zeros lie in a closed strip. Necessary and sufficient conditions are obtained for the related problem with real polynomials, and some classical theorems of de Bruijn and Pólya are extended. Specifically, we reveal new differential operators which map real polynomials into real polynomials whose zeros lie in a prescribed narrower strip; this is one of the properties that characterize a "strong universal factor" as defined by N. G. de Bruijn. The aforementioned results extend naturally to classes of entire functions whose zeros lie in a strip. Using elementary methods, we extend a related theorem of N. G. de Bruijn and J. Ilieff which states a sufficient condition for a function to have a Fourier transform with only real zeros. (Received September 17, 2013)

1096-46-2330 **Yuval Peres***, Microsoft Research, 1 Microsoft Way, Redmond, WA 98052. *Markov type and threshold embeddings.*

A metric space X has Markov Type 2 if the mean square displacement of stationary reversible finite Markov chains in X grows at most linearly. This notion, invented by Keith Ball (1992) for the purpose of Lipschitz extension, became later a key tool for proving distortion and compression lower bounds. We showed (with Assaf Naor, Oded Schramm and Scott Sheffield; Duke (2006)) that L^p spaces for $p > 2$ (and more generally, 2-smooth banach spaces as well as hyperbolic metric spaces) have Markov type 2, and this yielded a proof of a conjecture of Johnson and Lindenstrauss (1982) that for $1 < q < 2 < p < \infty$, any Lipschitz mapping from a subset of L^p to L^q has a Lipschitz extension defined on all of L^p. Recently we proved (with Jian Ding and James Lee; GAFA (2013)) that spaces with a threshold embedding to Hilbert space have Markov type 2; this covers doubling metric spaces and planar graphs. The proofs are based on Martingale decompositions. (Received September 17, 2013)

1096-46-2477 **Luke Rogers*** (luke.rogers@uconn.edu). *Magnetic operators on resistance spaces.*

In recent years a number of approaches have been developed for studying differential 1-forms on fractal spaces that admit a resistance form. This has enabled the study of certain differential equations which are of interest in physics; in particular, Hinz and Teplyaev have established the essential self-adjointness of magnetic Schrödinger operators on the space $L^2(\nu)$, where ν is the energy, or Kusuoka, measure associated to the resistance form. I will report on recent results on the self-adjointness of magnetic operators on $L^2(\mu)$, where μ is a Radon measure on the resistance space. This is joint work with Michael Hinz (Bielefeld). (Received September 17, 2013)

1096-46-2487 **Oleg Friedman*** (friedman001@yahoo.com), UNISA, Pretoria, RSA & Dep. of Math, Touro College/Lander College for Men, 7531 150-th Street, Kew Gardens Hills, NY 11367, and **Alexander A. Katz** (katza@stjohns.edu), St. John's University, SJC of LAS, Dep. of Math & CS, 8000 Utopia Parkway, SJH-334-i, Queens, NY 11439. *On Segal theorem about two-sided ideals for real C*- and real locally C*-algebras.*

It was proved by Segal that each closed two-sided ideal in a C*-algebra is automatically a *-ideal. This result was recently extended by Katz to locally C*-algebras. In the present paper this result is extended to real C*-algebras and real locally C*-algebras. (Received September 17, 2013)

47 ► Operator theory

1096-47-241 **Snehalatha Ballamoole*** (sb1244@msstate.edu), 410, Allen Hall, Starkville, MS MS 39759, **Thomas Len Miller** (miller@math.msstate.edu), 410 Allen Hall, Starkville, MS MS 39762, and **Vivien Glass Miller** (vivien@math.msstate.edu), 410 Allen Hall, Starkville, MS 39762. *A class of integral operators on spaces of analytic functions.*

We determine the spectrum and essential spectrum as well as resolvent estimates for a class of integral operators $T_{\mu,\nu} f(z) = z^{\mu-1}(1-z)^{-\nu} \int_0^z f(\xi)\xi^{-\mu}(1-\xi)^{\nu-1}\, d\xi$ acting on either the analytic Besov spaces or other Banach spaces of analytic functions on the unit disc, including the classical Hardy and weighted Bergman spaces as well as certain Dirichlet spaces and generalized Bloch spaces. Our results unify and extend recent work by Aleman and Persson, the current authors,and Albrecht and Miller. (Received August 22, 2013)

1096-47-260 **Zhengwei Liu*** (zhengwei.liu@vanderbilt.edu). *Composed inclusions of subfactors.*

The study of composed inclusions of two subfactors was initiated by D. Bisch and U. Haagerup. We will discuss the classification in the case that the principal graphs of the two subfactors are A_3 and A_4. We answer a question posed by D. Bisch and U. Haagerup in 1994. (Received August 24, 2013)

1096-47-276 **Darren C. Ong*** (darren.ong@rice.edu), Mathematics Department MS 136, Rice University, 6100 Main St, Houston, TX 77005, and **Paul Munger** (paul.e.munger@rice.edu), Mathematics Department MS 136, Rice University, 6100 Main St, Houston, TX 77005. *Results on the Hölder continuity of spectral measures of an extended CMV matrix.*

We will demonstrate new results about the Hölder continuity of the spectral measures of the extended CMV matrix, given power law bounds of the solution of the eigenvalue equation. We will apply our results to CMV matrices that act as transition matrices for certain models of quantum walks, and talk about how these results relate to dynamical spreading of these quantum walks. (Received August 26, 2013)

1096-47-315 **Wei He**, **Yueshi Qin** and **Rongwei Yang*** (ryang@albany.edu). *Numerical invariants of commuting isometric pairs.* Preliminary report.

Tuples of commuting isometries are fundamental examples for multivariable operator theory. Two related single operators, namely fringe (or pivotal) operator and defect operator, play important roles in the study of isometric pairs. The defect operator gives rise to a new equivalence relation, namely congruence, for isometric pairs. The congruence relation is much less rigid than the unitary equivalence, and hence possesses flexibility for a numerical classification of isometric pairs. (Received August 27, 2013)

1096-47-342 **Trieu L. Le*** (trieu.le2@utoledo.edu). *Weighted composition operators on the Drury–Arveson space.*

For a cardinal d, the Drury–Arveson space H^2_d can be identified as a reproducing kernel Hilbert space with kernel $K(z,w) = (1 - \langle z, w\rangle)^{-1}$, where z, w belong to the unit ball $\mathbb{B}_d$ of a d-dimensional Hilbert space. Let f be in H^2_d and φ be a holomorphic self-map of $\mathbb{B}_d$. The weighted composition operator $W_{f,\varphi}$ is defined on H^2_d by $W_{f,\varphi}h = f \cdot (h \circ \varphi)$. Researchers have been interested in studying how the operator theoretic properties of $W_{f,\varphi}$ affect the function theoretic properties of f, φ and vice versa. In this talk we shall discuss when the adjoint operator $W^*_{f,\varphi}$ is a weighted composition operator, or the inverse of a weighted composition operator. Consequently, we provide characterizations for $W_{f,\varphi}$ to be self-adjoint or unitary. (Received August 29, 2013)

1096-47-443 **Raphael Clouatre*** (rclouatre@uwaterloo.ca), 200 University Avenue West, Waterloo, Ontario N2L 3G1. *Unitary equivalence to Jordan models for weak contractions of class C_0.*

We study the problem of classification of Hilbert space contractions belonging to the class C_0 through the properties of some associated operator algebras. More precisely, we obtain results on the unitary equivalence of weak contractions of class C_0 to their Jordan models under an assumption on their commutants. In particular, our work addresses the case of arbitrary finite multiplicity. The main tool is the theory of boundary representations due to Arveson.

Our approach also raises some interesting questions about general non-self-adjoint operator algebras and possible refinements of Paulsen's theorem on completely bounded homomorphisms. (Received September 03, 2013)

1096-47-444 **John D. Williams*** (jwilliams@math.tamu.edu), Texas A&M, Department of Mathematics, Mail Stop 3368, College Station, TX 77843-3368. *Analytic Function Theory for Operator-Valued Free Probability.*

It is a classical result in complex analysis that the class of functions that arise as the Cauchy transform of probability measures may be characterized entirely in terms of their analytic and asymptotic properties. Such transforms are a main object of study in non-commutative probability theory as the function theory encodes information on the probability measures and the various convolution operations. In extending this theory to operator-valued free probability theory, the analogue of the Cauchy transform is a non-commutative function with domain equal to the non-commutative upper-half plane. In this paper, we prove an analogous characterization of the Cauchy transforms, again, entirely in terms of their analytic and asymptotic behavior. We further characterize those functions which arise as the Voiculescu transforms of $\boxplus$-infinitely divisible $\mathcal{B}$-valued distributions. As an immediate consequence this theorem, combined with an existing result of Popa and Vinnikov, may be used to produce analogues of the Nevanlinna representation for non-commutative functions with the appropriate asymptotics. In addition to this, we may define semigroups of completely positive maps associated to infinitely divisible distributions. (Received September 03, 2013)

1096-47-459 **Milivoje Lukic*** (milivoje.lukic@rice.edu), Rice University, 6100 Main Street, Mathematics MS 136, Houston, TX 77005. *Bounded variation conditions and absolutely continuous spectrum.*

It is well known that ℓ^1 perturbations of the free Jacobi matrix have purely a.c. (absolutely continuous) spectrum on $(-2,2)$ and ℓ^2 perturbations have a.c. spectrum on $(-2,2)$. For perturbations of slower decay, bounded variation conditions turn out to be natural conditions for existence of a.c. spectrum. In this talk, we will discuss some recent results which show that certain ℓ^1 and ℓ^2 bounded variation conditions on the Jacobi coefficients imply purely a.c. spectrum or a.c. spectrum on suitable intervals. (Received September 04, 2013)

1096-47-461 **Gelu F Popescu*** (gelu.popescu@utsa.edu). *Berezin Transforms on Noncommutative Varieties.*

We study the structure of large classes of noncommutative varieties, determine their elements and classify them up to unitary equivalence. This study can be seen as an attempt to initiate noncommutative algebraic geometry in polydomains. Using noncommutative Berezin transforms, we develop an operator model theory and dilation theory for varieties in noncommutative polydomains. This includes various commutative cases which are closely connected to the theory of holomorphic functions in several complex variables and algebraic geometry. (Received September 04, 2013)

1096-47-480 **Zeljko Cuckovic*** (zcuckovi@math.utoledo.edu), University of Toledo, Department of Mathematics, 2801 W. Bancroft St., Toledo, OH 43606, and **Sonmez Sahutoglu**, University of Toledo, Department of Mathematics, 2801 W. Bancroft St., Toledo, OH 43606. *Axler-Zheng type theorem on domains in $\mathbb{C}^{\mathsf{K}}$.*

Axler-Zheng theorem characterizes the compactness of finite sums of finite products of Toeplitz operators acting on the Bergman space on the unit disk in terms of the Berezin transform of the operators. We prove a version of Axler-Zheng's theorem for a class of smooth bounded pseudoconvex domains in $\mathbb{C}^{\mathsf{K}}$. (Received September 04, 2013)

1096-47-485 **Kristin Elizabeth Luery*** (kristin.luery@uc.edu). *Composition operators with closed range.*

We show that a composition operator on the Hardy space of the disk is bounded below if and only if it is bounded below on the Szegő kernel functions. This provides a direct geometric correspondence between the conditions of Cima, Thomson, and Wogen from 1974; Zorboska from 1994; and Lefèvre, Li, Queffélec, and Rodríguez-Piazza from 2012 for a composition operator to have closed range. (Received September 04, 2013)

1096-47-613 **Joseph A Ball*** (joball@math.vt.edu), Department of Mathematics, Virginia Tech, Blacksburg, VA 24061. *Multidimensional linear systems and multivariable weighted Bergman spaces.* Preliminary report.

It is well known that subspaces of the Hardy space over the unit disk which are invariant under the backward shift occur as the image of an observability operator associated with a discrete-time linear system with stable state-dynamics, while forward shift-invariant subspaces have a Beurling-Lax representation as the image of an inner function applied to a Hardy space. Moreover, the inner Beurling-Lax representer can be exhibited as the transfer function of an explicit conservative discrete-time input/state/output linear system. Recently the speaker together with Vladimir Bolotnikov (College of William and Mary) have developed these ideas for a general class of weighted Bergman spaces over the unit disk, expanding on original ideas of Anders Olofsson. This talk will discuss further extensions of these ideas to multivariable weighted Bergman spaces, both in commutative and in freely noncommutative settings. (Received September 07, 2013)

1096-47-728 **Arsalan Chademan Shademan*** (achademan@gmail.com), 14414 Rancho Del Prado Trl., San Diego, CA 92127. *Angle reserving linear ransformations.* Preliminary report.

Let E be a real vector space equipped with an inner product $x \cdot y$ and the corresponding norm $\|x\|$. We assume that E is non trivial $\dim E \geq 1$, and $T: E \to E$ is a linear transformation. As usual T is *isometric* if $\|Tx\| = \|x\|$ for all $x \in E$; T is a *similarity* if it is isometric up-to a positive constant. It is well known that T is a similarity if and only if it preserves orthogonality, i.e. $x \cdot y = 0$ implies $Tx \cdot Ty = 0$ for all $x, y \in E$. A similarity preserves any angle which means that for all $x, y \in E$ the equality $\|x\|\ \|y\|(Tx \cdot Ty) = \|Tx\|\ \|Ty\|(x \cdot y)$ holds. In this paper we prove that in an inner product space, linear transformations preserving angles with a given single magnitude $0 < \alpha < \pi$, are similarities. In other words, for a linear transformation T to be a similarity it is sufficient that there exists an $0 < \alpha < \pi$ such that for all $x, y \in E$, the equality $x \cdot y = \|x\|\|y\| \cos\alpha$ implies $Tx \cdot Ty = \|Tx\|\|Ty\| \cos\alpha$. (Received September 09, 2013)

1096-47-974 **Matthew A Fury*** (maf44@psu.edu), Penn State Abington, 1600 Woodland Road, Abington, PA 19001. *Regularization of nonautonomous ill-posed problems from linear to quasi-linear.* Preliminary report.

A common approach to studying an ill-posed problem involves the regularization of the problem in which a known solution is approximated by the solution of a closely-defined well-posed problem. This method has been studied in recent literature for several versions of the abstract Cauchy problem $du/dt = Au, 0 \leq t < T$, $u(0)$ where A is an operator in a Banach space, and with applications to a wide class of partial differential equations including the backward heat equation. In this presentation, we will review recent results proved by the author concerning the regularization of nonautonomous ill-posed problems where the operator A is replaced by the nonconstant operator $A(t)$. We will highlight the differences in the structure of the regularization depending on the properties of the operators $A(t)$ and also depending on the type of problem being considered such as inhomogeneous, or semi-linear, for example. Finally, an introduction to quasi-linear equations with be given with a discussion on how regularization may be extended to such problems. (Received September 11, 2013)

1096-47-979 **Zhongwei Shen*** (zzs0004@auburn.edu), Auburn University, 221 Parker Hall, Auburn, AL 36849. *Scattering theory of a class of Schrödinger operators with sparse potentials.* Preliminary report.

We present recent results about the scattering theory of a class of continuum Schrödinger operators with sparse potentials. First, we establish the limiting absorption principle for both modified free resolvents and modified perturbed resolvents. This actually is a weak form of the classical limiting absorption principle. Then, we prove the existence and completeness of wave operators. In particular, the absolutely continuous spectrum coincides with $[0, \infty)$ (Received September 11, 2013)

1096-47-1079 **Lance Nielsen*** (lnielsen@creighton.edu), Creighton University, Department of Mathematics, 2500 California Plaza, Omaha, NE 68178. *Towards a Comprehensive Stability Theory for Feynman's Operational Calculus: The Time Independent Setting.* Preliminary report.

Via a general construction, we are able to establish a quite general and comprehensive stability theory for Feynman's operational calculus 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 B. Jefferies and G.W. Johnson in the late 90's), 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 to this time is contained, essentially in its entirety, in the principle result of this paper. Moreover, this theorem allows immediate, and rather far-reaching, extensions of the stability theory that, until now, have not been possible. (Received September 12, 2013)

1096-47-1140 **Adam E Broschinski*** (aebroschinski@ufl.edu). *Eigenvalues of Self-Adjoint Toeplitz Operators with respect to a Constrained Algebra.*

By working with all collection of all the Sarason Hilbert Hardy spaces for the annulus algebra an improvement to the results of Aryana and Clancey on eigenvalues of self-adjoint Toeplitz operators on an annulus is obtained. The ideas allow us to analyze eigenvalues in the gap of self-adjoint Toeplitz operators on the Neil algebra. We will discuss Toeplitz operators on n-holed domains and other constrained algebras too. (Received September 13, 2013)

1096-47-1225 **J E Pascoe*** (jpascoe@math.ucsd.edu). *The noncommutative lifting principle.*

The *noncommutative lifting principle* is a guiding principle which states that if a theorem in several complex holds by the virtue of multivariable operator theoretic methods, then there is an analogue in the noncommutative setting. We give a survey of concrete successful applications of this principle including the transfer function realization formula for bounded analytic functions, the Positivestellensatz, and Löwner's theorem on the continuation of matrix monotone functions. (Received September 13, 2013)

1096-47-1285 **Anna Skripka*** (askripka@unm.edu). *Perturbation of multivariable operator functions.* Preliminary report.

We will discuss trace perturbation results for multivariable functions of commuting contractions. (Received September 14, 2013)

1096-47-1289 **Anna Skripka*** (askripka@unm.edu). *Asymptotic expansions of trace functionals.* Preliminary report.

We will discuss Taylor-like approximations of traces of operator functions. (Received September 14, 2013)

1096-47-1295 **Kenneth R. Davidson*** (krdavids@uwaterloo.ca), Pure Mathematics Dept., University of Waterloo, Waterloo, ON N2L 3G1, Canada, and **Michael Hartz** and **Orr M. Shalit**. *Multipliers of embedded discs.*

We consider a number of examples of multiplier algebras on Hilbert spaces associated to discs embedded into a complex ball in order to examine the isomorphism problem for multiplier algebras on complete Nevanlinna-Pick reproducing kernel Hilbert spaces. In particular, we exhibit uncountably many discs in the infinite dimensional ball which are multiplier biholomorphic but have non-isomorphic multiplier algebras. In finite balls, we provide a counterpoint to a result of Alpay, Putinar and Vinnikov by providing a proper rational biholomorphism of the disc onto a variety in the 2-ball such that the multiplier algebra is not all bounded analytic functions. (Received September 14, 2013)

1096-47-1305 **Hugo J Woerdeman*** (hugo@math.drexel.edu), Department of Mathematics, Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104. *Determinantal representations of stable polynomials.*

A polynomial $p(z) = p(z_1, \ldots, z_d)$ is called *stable* if $p(z) \neq 0$ for $z \in \overline{\mathbb{D}}^d$, where $\mathbb{D}$ is the open unit disk in $\mathbb{C}$ and $\overline{\mathbb{D}} = \mathbb{D} \cup \mathbb{T}$ is its closure. It is an open question whether every multivariable stable polynomial $p(z)$ with $p(0) = 1$ can be written as

$$p(z) = \det(I - KZ(z)),$$

where $Z(z)$ is a diagonal matrix with coordinate variables on the diagonal and K is a strict contraction. For one and two variable polynomials such a representation always exists; in one variable it is an easy consequence of the fundamental theorem of algebra, while in two variables it follows from a result by A. Kummert. As a variation, we show in this paper that independent of the number of variables every stable multivariable polynomial p, with $p(0) = 1$, has a determinantal representation

$$p(z) = \det(I - M(z)),$$

where $M(z)$ is a matrix valued rational function with $\|M(z)\| \leq 1$ and $\|M(z)^n\| < 1$ for $z \in \mathbb{T}^d$ and $M(az) = aM(z)$ for all $a \in \mathbb{C} \setminus \{0\}$. In fact, the existence of such a representation characterizes stable polynomials. (Received September 14, 2013)

1096-47-1358 **Pamela Gorkin*** (pgorkin@bucknell.edu), Department of Mathematics, Bucknell University, Lewisburg, PA 17837, and **Sandra Pott** and **Brett D. Wick**. *Model spaces and thin interpolating sequences.*

In this talk, we present connections between so-called thin Blaschke products and model spaces. We discuss several ways of thinking about thin sequences, some via the Gram matrix and others via interpolation in the Hardy spaces. We use an operator theoretic approach to connect thin sequences to model spaces. (Received September 15, 2013)

1096-47-1385 **Bhupendra Paudyal*** (bpaudya@rockets.utoledo.edu). *Eigenfunctions of composition and weighted composition operators.*

Let ϕ be a holomorphic self map of the unit disk $\mathbb{D}$ and u be any holomorphic map on D with $\phi(0) = 0$ and $0 < \phi'(0) < 1$. I will discuss eigenvalues and eigenfuntions of C_ϕ and uC_ϕ on the set of holomorphic functions $H(\mathbb{D})$. Then I will provide the conditions on u and ϕ that ensure that all these eigenfunctions (as of $H(\mathbb{D})$) are also the eigenfunctions of the bounded operator uC_ϕ on α-Bloch spaces $\mathcal{B}_\alpha$, $0 < \alpha < \infty$. (Received September 15, 2013)

1096-47-1398 **D Drissi*** (drissi@sci.kuniv.edu.kw), Department of Mathematics, Kuwait University, P.O.Box 5969, Kuwait, Kuwait. *Resolvent algebras and Deddens algebras for rank-one and finite rank perturbations operators.* Preliminary report.

For a given operator A on a Hilbert space H, and let $D_n(A)$ be a sequence of invertible operators on H. We consider the algebras

$$B = \{T \in L(H) : \sup_{n>0} \|D_n(A)TD_n(A)^{-1}\| < \infty\}$$

First, we characterize these algebras when A is a rank-one / finite rank perturbation operator, and their commutant. This may help to generalize Lomonosov's Lemma on the hyperinvariant subspaces. (Received September 16, 2013)

1096-47-1429 **Raul E. Curto*** (raul-curto@uiowa.edu), Department of Mathematics, University of Iowa, Iowa City, IA 52242. *A new approach to the sextic truncated moment problem.*

For a degree $2n$ real bivariate moment sequence $\beta \equiv \beta^{(2n)} = \{\beta_{ij}\}_{i,j\in Z_+, i+j\leq 2n}$ to have a representing measure μ, it is necessary for the associated moment matrix $M(n)$ to be positive semidefinite, and for the algebraic variety associated to β, $\mathcal{V}_\beta \equiv \mathcal{V}(M(n))$, to satisfy rank $M(n) \leq$ card $\mathcal{V}_\beta$ as well as the following consistency condition: if a polynomial $p(x,y) \equiv \sum_{ij} a_{ij}x^i y^j$ of degree at most $2n$ vanishes on $\mathcal{V}_\beta$, then the *Riesz functional* $\Lambda(p) \equiv p(\beta) := \sum_{ij} a_{ij}\beta_{ij} = 0$.

Let $n = 3$, assume that $M(3) \geq 0$, and that it satisfies the variety condition rank $M(3) \leq$ card $\mathcal{V}_\beta$ as well as consistency. Also assume that $M(3)$ admits at least one *cubic* column relation. In joint work with Seonguk Yoo, we prove the existence of a related matrix $\widetilde{M(3)}$ with rank $\widetilde{M(3)} <$ rank $M(3)$ and such that each representing measure for $\widetilde{M(3)}$ gives rise to a representing measure for $M(3)$. As a concrete application, we discuss the case when rank $M(3) = 8$ and card $\mathcal{V}(M(3)) \leq 9$. (Received September 15, 2013)

1096-47-1518 **Genady Ya. Grabarnik*** (grabarng@stjohns.edu), 126 brambach rd, scarsdale, NY 10583, and **Ben-Zion Rubshtein**, Math Department, Ben Gurion University, Beer Sheva, Israel. *Refinement of the Yosida-Hewitt decomposition of singular functionals on operator rearrangement invariant spaces.*

Let M be a von Neumann algebra with faithful semifinite normal trace τ. Rearrangement invariant Banach subspaces of measurable operators affiliated with M, τ were introduced by Grothendieck and later by Yeadon. Recently the Yosida-Hewitt decomposition of singular functionals on operator RI spaces was considered by Dodds and Pagter. We refine the Yosida-Hewitt-Takesaki decomposition of singular functionals on operator RI spaces, show existence and spacial character of the decomposition. (Received September 20, 2013)

1096-47-1535 **scott a mccullough*** (sam@ufl.edu). *Noncommutative Inequalities.* Preliminary report.

The talk will cover aspects of inequalities for non-commutative functions in free *-algebras. At this point we have:

A. Free *-algebra versions of the classical real algebraic geometry description, or positivstellensatze (resp. nullstellensatze), which provides an algebraic certificate for a polynomial q to take postive definite (resp. zero) values on the set where another, q, takes positive definite (resp. zero) values;

B. Classifications of convex rational functions, varieties and open sets. There are shockingly few;

C. An emerging picture of free convex hulls and projections of free semi-algebraic sets;

D. Some theory of changes of variables to achieve non-commutative convexity and the relationship to positivstellensatze;

E. Other.

The work originates in trying to develop some theory for studying the matrix inequalities which are ubiquitous in linear engineering systems and control. The talk will select a topic from the list above and will be co-ordinated with the speaker's collaborators who are in attendence. (Received September 16, 2013)

1096-47-1570 **Christopher Ramsey*** (cir6d@virginia.edu), 141 Cabell Drive, Kerchof Hall, Department of Mathematics, P.O. Box 400137, Charlottesville, VA 22904. *Triangular algebras vs. Tensor algebras.*

In 1959 Kadison and Singer defined an operator algebra T to be triangular if $T \cap T^*$ is abelian. The tensor algebra of a C*-correspondence over a commutative C*-algebra is then triangular, which begs the question whether all triangular algebras are tensor algebras. We will look at this question in the case of triangular UHF algebras. (Received September 16, 2013)

1096-47-1613 **Nicola Watson*** (nicola.watson@utoronto.ca), Room 6290, 40 St George Street, Toronto, Ontario M5S 2E4, Canada. *Nuclearity for C^*-algebras with real rank zero.* Preliminary report.

Since the 1970s, attempts to classify C^*-algebras have focused on those that are nuclear, and the majority of these attempts have not been dependent on von Neumann algebra theory. In this talk, we prove an intrinsic characterisation of nuclearity for C^*-algebras with real rank zero, in terms of finite dimensional subalgebras. This characterisation shows how natural the concept of finite nuclear dimension is for these algebras, and potentially makes some interesting C^*-algebraic questions susceptible to von Neumann algebra techniques. (Received September 16, 2013)

1096-47-1664 **Joshua Isralowitz*** (jisralowitz@albany.edu). *Schatten class Toeplitz operators on generalized Fock spaces.* Preliminary report.

In this talk we will characterize Schatten class Toeplitz operators on generalized Fock spaces. Furthermore, we will briefly discuss the considerably more difficult problem for Hankel operators and discuss some interesting problems related to this work. This is joint work with Jani Virtanen and Lauren Wolf. (Received September 16, 2013)

1096-47-1709 **Scott M. LaLonde*** (scott.m.lalonde.gr@dartmouth.edu), 6188 Kemeny Hall, Dartmouth College, Hanover, NH 03755. *Results on Nuclearity and Exactness for Groupoid Crossed Product C^*-algebras.* Preliminary report.

In 1978, P. Green established that the class of nuclear C^*-algebras is stable under crossed products by amenable groups. It was later proven by E. Kirchberg that the crossed product of an exact C^*-algebra by an amenable group is again exact. In this talk we will discuss generalizations of these two longstanding results to crossed products by locally compact groupoids. In particular, we show that if G is a measurewise amenable groupoid acting on a nuclear C^*-algebra A, then the crossed product $A \rtimes G$ is nuclear. We also show that if G is an exact groupoid and A is an exact C^*-algebra, then the reduced crossed product $A \rtimes_r G$ is exact. If G is amenable, then this implies that the full crossed product is exact. (Received September 16, 2013)

1096-47-1745 **Waleed K. Al-Rawashdeh*** (walrawashdeh@mtech.edu), Montana Tech, Department of Mathematical Sciences, Butte, MT 59701. *Weighted Composition Operators between Weighted Bergman and S^p Spaces.*

Let φ be an analytic self-map of open unit disk $\mathbb{D}$ and ψ is analytic on $\mathbb{D}$. The weighted composition operator induced by φ with weight ψ is given by $\left(W_{\psi,\varphi}f\right)(z) = \psi(z)f(\varphi(z))$, for z in $\mathbb{D}$ and f analytic on $\mathbb{D}$. 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^p_α 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 weighted composition operators act between weighted Bergman A^p_α and S^q spaces for $1 \leq p, q \leq \infty$. (Received September 16, 2013)

1096-47-1854 **Kenneth R. Davidson**, **Adam H. Fuller*** (afuller7@math.unl.edu) and **Evgenios T. A. Kakariadis**. *Semicrossed Products of Operator Algebras by Semigroups.* Preliminary report.

Group dynamical systems and the crossed product algebras they generate have long been a source of interesting operator algebras.The natural generalization, inspired by concrete examples of operator algebras, is to consider semigroup dynamical systems. That is, if A is an operator algebra and $\{\alpha_s\}_{s\in S}$ is a representation of a semigroup S by endormorphisms on A. The goal is to construct a larger algebra, containing A, that also encodes the information of the action of S on A. The nonself-adjoint versions of these algebras are called semicrossed product algebras.

Recent work has shown that the C^*-envelope of a semicrossed algebra can be useful in distinguishing dynamical systems by their semicrossed products.

However, whilst in the C^*-literature a wide class of semigroups are consider for crossed-products, the majority of the work on semicrossed products has been carried out the in case when $S = \mathbb{Z}_+$.

In this talk we present some recent results in semicrossed products arising from a wider class of positive cones. These include, but are not limited to, the positive cones of abelian lattice ordered groups. (Received September 16, 2013)

1096-47-1933 **John D. Williams*** (jwilliams@math.tamu.edu), Mailstop 3368, Dept. Of Mathematics, Texas A&M, Colleg Station, TX 778433368. *Infinite Divisibility and Semigroups Indexed by Completely Positive Maps in Free Probability.*

Expanding on some recent non-commutative function theoretic results, we will show that to each $\boxplus$-infinitely divisible B-valued distribution, one may associate a semigroup whose index set is the set of all completely positive self maps of the C*-algebra B. This has long been expected as there are existing positive results, including a recent theorem due to Anshelevich, Belinschi, Fevrier and Nice, that pointed to this as the natural generalization of semigroups of distributions in operator-valued free probability. Time permitting, we will present recent function theoretic work on this subject. (Received September 16, 2013)

1096-47-1981 **Hyun Kwon*** (hkwon5@as.ua.edu), Department of Mathematics, Box 870350, 345 Gordon Palmer Hall, The University of Alabama, Tuscaloosa, AL 35487. *Similarity of Cowen-Douglas Operators in the Multivariable Setting.* Preliminary report.

In this talk, I will address some issues one faces when dealing with the similarity question of Cowen-Douglas operators whose eigenvalues form an open set in $\mathbb{C}^N$. A few observations will be made in comparison with the single variable case. (Received September 17, 2013)

1096-47-2017 **Bingyang Hu**, **Le Hai Khoi** and **Ruhan Zhao*** (rzhao@brockport.edu), Department of Mathematics, SUNY Brockport, Brockport, NY 14420. *Topological structure of the spaces of composition operators on Hilbert spaces of Dirichlet series.*

We study some topological properties of the space of bounded composition operators on some Hilbert spaces of Dirichlet series. Among other results, we characterized isolation points on such spaces, and showed that all compact composition operators are in the same path component. This is a joint work with Bingyang Hu and Le Hai Khoi. (Received September 17, 2013)

1096-47-2161 **Liangying Jiang*** (liangying1231@163.com), Department of Applied Mathematics, Shanghai Finance University, Shanghai, 201209, Peoples Rep of China, and **Zhihua Chen**. *Spectra of linear fractional composition operators on $H^2(B_N)$.*

We characterize the spectra of composition operators on the Hardy space $H^2(B_N)$, when whose symbols are elliptic or hyperbolic linear fractional self-maps of the unit ball B_N. Therefore, combining with a previous result obtained by Bayart, the spectra of all linear fractional composition operators on $H^2(B_N)$ are completely determined. (Received September 17, 2013)

1096-47-2209 **Gabriel T Prajitura***, Mathematics Department, SUNY Brockport, 350 New Campus Drive, Brockport, NY 14420. *Cesaro Matrices: Where do they all come from.* Preliminary report.

We will present a class of operators on l^2 which are generated by iterations of the method that generates the classical Cesaro matrix. We will discuss the boundedness, the norm and the spectrum of these operators. (Received September 17, 2013)

1096-47-2274 **Debendra P. Banjade*** (dpbanjade@crimson.ua.edu), The University of Alabama, Department of Mathematics, P. O. Box 870350, Tuscaloosa, AL 35487. *Generalized Corona Theorem and Wolff's Ideal Theorem on the Multiplier Algebra of Weighted Dirichlet Spaces, and on Q_p Spaces.*

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 will discuss the extension of Wolff's Theorem and the generalized Corona Theorem to the multiplier algebra on weighted Dirichlet spaces. Of course, operator theory approach and complete Nevanlinna-Pick kernels will play a main role. Also, we will mention our conjecture towards the multivariable case. Additionally, we provide an analogous results on möbious invariant Dirichlet spaces, so called Q_p spaces for $0 < p < 1$. For Q_p spaces, $\bar{\partial}$ - equations and p - Carleson measures will be crucial tools for us. This talk is based on joint work with Tavan T. Trent. (Received September 17, 2013)

1096-47-2400 **Reema Al-Aifari*** (reema@alaifari.com), Pleinlaan 2, Vakgroep DWIS, 1050 Brussels, Belgium, and **Alexander Katsevich**. *Analysis of the truncated Hilbert transform arising in limited data tomography.*

In Computerized Tomography a 2D or 3D object is reconstructed from projection data (Radon transform data) from multiple directions. When the X-ray beams are sufficiently wide to fully embrace the object and when the beams from a sufficiently dense set of directions around the object can be used, this problem and its solution are well understood. When the data are more limited the image reconstruction problem becomes much more challenging; leading to configurations where only a subregion of the object is illuminated from all angles.

In this presentation we consider a limited data problem in 2D Computerized Tomography which gives rise to a restriction of the Hilbert transform as an operator H_T from $L^2(a_2, a_4)$ to $L^2(a_1, a_3)$ for real numbers $a_1 < a_2 < a_3 < a_4$.

We relate the operator H_T to a self-adjoint two-interval Sturm-Liouville problem, which allows to explore the spectrum of $H_T^* H_T$. We find that H_T is not compact but its inversion is ill-posed. With these results, we then address the question of the rate of convergence of the singular values. We conclude by illustrating the properties obtained for the SVD of H_T numerically. (Received September 17, 2013)

1096-47-2410 **Mihai Popa*** (mihai.popa@utsa.edu), University of Texas at San Antonio, Department of Mathematics, ONE UTSA Circle, San Antonio, TX 78249, and **James A Mingo** and **Yong Jiao**. *On Second Order Fluctuations for Some Classes of Random Matrices.*

The talk presents several recent results, joint work with J. A. Mingo and Y. Jiao, concerning asymptotic behaviors of certain classes of random matrices. We have obtained the asymptotic real second order freeness for Haar Orthognal random matrices, asymptotic freenes between a Haar unitary random matrics and its transpose as well as properties of certain random matrices with non-commuting entries. (Received September 17, 2013)

1096-47-2488 **George R Exner*** (exner@bucknell.edu), Department of Mathematics, Bucknell University, Lewisburg, PA 17837, and **Il Bong Jung**, **Mi Ryeong Lee** and **Sun Hyun Park**. *A range for quadratic hyponormality.* Preliminary report.

Let W_α be the unilateral weighted shift operator on Hilbert space associated with weight sequence α. An operator T is quadratically hyponormal if $T + sT^2$ is hyponormal for all complex s; for weighted shifts, and using the Nested Determinant Test, this reduces to non-negativity, for all $t \geq 0$, of certain polynomials $d_n(t)$, $n = 1, 2, \ldots$. A strong way to achieve this is to insist that every coefficient arising in any d_n is non-negative: this is positive quadratic hyponormality. For the weight sequence $\alpha : 1, 1, \sqrt{x}, (\sqrt{u}, \sqrt{v}, \sqrt{w})^\wedge$ (where $(\sqrt{u}, \sqrt{v}, \sqrt{w})^\wedge$ indicates the sequence is completed by the recursive tail arising in Stampfli's completion of three increasing weights to a sequence yielding a subnormal shift), we show that the set of x for which there exist u, v, and w resulting in quadratic hyponormality is $(1, 2)$, which is also the analogous set for positive quadratic hyponormality. (Received September 17, 2013)

1096-47-2522 **Alexandra V Pasi*** (lexipasi@gmail.com) and **Richard Wellman**. *Gaussian Left-Definite Variations of the Laguerre and Jacobi Differential Expressions and Their Applications to Learning Theory.*

We present the Gaussian left-definite variations of the Laguerre and Jacobi differential expressions. Unlike other left-definite variations of classical differential equations that have been previously studied, the expressions we present are of different orders than the original self-adjoint operators they are similar to. Additionally, while both the Laguerre and Jacobi differential expressions are singular, their Gaussian left-definite variations are regular. The computability of these regular expressions makes them especially well-suited for applications to learning theory. We discuss how these expressions may be used in the creation of novel kernels for learning machines. (Received September 17, 2013)

1096-47-2550 **Duaine S Lewis***, Department of Mathematics, The University of the West Indies, Cave Hill, P.O. Box 64, Bridgetown, St Michael BB11000, Barbados, and **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. *An upper bound on the Kolmogorov widths of a certain family of integral operators.* Preliminary report.

We consider the family of integral operator $(K_\alpha f)(x)$ from $L^p[0,1]$ to $L^q[0,1]$ where $(K_\alpha f)(x) := \int_0^1 f(y)(1 - xy)^{\alpha-1} dy$ with $0 < \alpha < 1$; the main objective is to find upper bounds for the Kolmogorov widths. The n-th Kolmogorov width is the infimum of the deviation of $(K_\alpha f)$ from an n-dimensional subspaces of $L^q[0,1]$ (where the infimum is taken over all n-dimensional subspaces), and is therefore a measure how well $(K_\alpha f)$ can be approximated. We find upper bounds for the Kolmogorov widths in question that decrease exponentially in n. (Received September 17, 2013)

1096-47-2639 **Nathan P Clements*** (clementsuwyo@gmail.com). *the spectrum of a hypercyclic operator.*

A bounded linear operator T on a Banach space X is said to be hypercyclic if there exists some vector $x \in X$ so that its orbit $\{x, Tx, T^2x, T^3x, ...\}$ is dense in X. Hypercyclicity is studied because of its connection to the invariant subspace problem, a famous open problem in functional analysis. A dense orbit is also a necessary condition for chaotic operators.

In this talk, we will explore questions about the nature of the spectrum of a hypercyclic operator. We will discuss a classic hypercyclic result that every component of the spectrum must intersect the unit circle, and then will discuss a new result concerning conditions about the cardinality of the spectrum. This result allows us to make several observations about the nature of the spectrum of a hypercyclic operators, some of which shall be discussed. (Received September 17, 2013)

1096-47-2745 **Allan P. Donsig** and **David Milan*** (dmilan@uttyler.edu). *Finitely Aligned Semigroupoids and Tight C^*-algebras.* Preliminary report.

Exel defined semigroupoid C*-algebras as a class including graph algebras and generalizations such as higher-rank graph algebras. He showed in the singly aligned case that these algebras are the tight algebras of inverse semigroups. We extend his construction to the inverse semigroup S of a finitely aligned semigroupoid and give a correspondence between representations of the semigroupoid and tight representations of S. (Received September 18, 2013)

49 ► Calculus of variations and optimal control; optimization

1096-49-153 **Frank Morgan*** (frank.morgan@williams.edu). *The Log-Convex Density Conjecture.* Preliminary report.

The Log-Convex Density Conjecture says that in R^n with a log-convex radial density, balls about the origin minimize weighted perimeter for given weighted volume. We'll discuss some recent progress and generalizations following earlier work by undergraduates. (Received August 10, 2013)

1096-49-185 **Lisa J Larsson*** (lisa.powers@mail.mcgill.ca), **Rustum Choksi** and **Jean-Christophe Nave**. *Centroidal Voronoi Tessellations of Rigid Shapes: A Variational Perspective.*

The Centroidal Voronoi Tessellation (CVT) is an optimal configuration of points in convex domains. These tessellations are used in many areas from facility location problems to mesh generation. We extend the notion of a CVT from points to rigid shapes in two and three dimensions. Given a finite set of shapes, we optimize their location via translation and rotation by minimizing a suitable cost function. Differentiating the cost function reduces to differentiating the solution to a nonlinear PDE-the Eikonal Equation-with respect to its boundary condition (the zero contour). The CVT optimization problem for points is typically tackled using quasi-Newton methods and an iterative algorithm called Lloyd's method–we will discuss extensions of both to the rigid shape case. The optimization problem for rigid shapes is challenging in part because integrals over the Voronoi regions generated by shapes must be calculated; these regions are non-convex and a priori unknown. The novelty of our algorithm is that the boundaries of the Voronoi regions are never explicitly calculated. We describe how the Eikonal Equation enters in the problem, and present detailed theoretical and numerical results. (Received September 16, 2013)

1096-49-227 **Alexander J Zaslavski*** (ajzasl@tx.technion.ac.il), Department of Mathematics, Technion-Israel Institute of Technology, Haifa, Israel. *Structure of solutions of discrete-time optimal control systems.*

We present necessary and sufficient conditions for turnpike properties of approximate solutions of nonautonomous discrete-time optimal control systems arising in economic dynamics which are determined by sequences of lower semicontinuous objective functions. To have these properties means that the approximate solutions of the problems are determined mainly by the objective functions, and are essentially independent of the choice of intervals and endpoint conditions, except in regions close to the endpoints. (Received August 21, 2013)

1096-49-285 **Jing Qin*** (jxq@ucla.edu), UCLA Mathematics Department, Box 951555, Los Angeles, CA 90024, and **Weihong Guo** (wxg49@case.edu), 10900 Euclid Ave, Department of Mathematics, Cleveland, OH 44106. *Prior Information Guided Image Denoising and Reconstruction.*

Prior information of image, including geometric prior and local/global image regularities, plays an important role in image processing and compressive sensing(CS). In this talk, we will discuss how to incorporate image priors into image denoising and reconstruction to enhance the performance significantly. We propose to efficiently balance noise removal and feature preservation using segmentation and more general geometry extraction transforms. Explained in nonlocal-means (NL-means) framework, we introduce mutual position function to ensure averaging is only taken over pixels in the same segmentation phase, and provide a convolution kernel and weight function selection scheme to further improve the performance. To address unreliable segmentation due to more excessive noise, we use a feature extraction transform that is more general than segmentation and less sensitive to noise. The proposed method comes with an automatic parameter selection scheme, and can be easily adapted for various types of noise, ranging from Gaussian, Poisson, Rician to Ultrasound noise etc. Effectiveness of gradient priors in boosting image reconstruction will also be briefly mentioned in the CS framework. (Received August 26, 2013)

1096-49-295 **Nicholas Ryder*** (nick.ryder@rice.edu), 1601 Rice Blvd, Houston, TX 77005, Plano, TX 77005, and **Pak Hin Li**, **Baris Evren Ugurcan** and **Robert S. Strichartz**.
Extensions and their Minimizations on the Sierpinski Gasket.

We study the extension problem on the Sierpinski Gasket (SG). In the first part we consider minimizing the functional $\mathcal{E}_\lambda(f) = \mathcal{E}(f,f) + \lambda \int f^2 d\mu$ with prescribed values at a finite set of points where $\mathcal{E}$ denotes the energy (the analog of $\int |\nabla f|^2$ in Euclidean space) and μ denotes the standard self-similiar measure on SG. We explicitly construct the minimizer $f(x) = \sum_i c_i G_\lambda(x_i, x)$ for some constants c_i, where G_λ is the resolvent for $\lambda \geq 0$. We minimize the energy over sets in SG by calculating the explicit quadratic form $\mathcal{E}(f)$ of the minimizer f. We consider properties of this quadratic form for arbitrary sets and then analyze some specific sets. One such set we consider is the bottom row of a graph approximation of SG. We describe both the quadratic form and a discretized form in terms of Haar functions which corresponds to the continuous result established in a previous paper. We study a similar problem this time minimizing $\int_{SG} |\Delta f(x)|^2 d\mu(x)$ for general measures. In both cases, by using standard methods we show the existence and uniqueness to the minimization problem. We then study properties of the unique minimizers. (Received August 27, 2013)

1096-49-369 **Mohsen Razzaghi*** (razzaghi@math.msstate.edu), Department of Mathematics & Statistics, P.O. Box MA, 410 Allen Hall, Mississippi State, MS 39762. *Solution of delay systems in optimization problems by hybrid functions.*

Orthogonal functions and polynomial series, have recently been used to solve various problems of dynamical systems. The main advantage of using orthogonal functions and polynomial series is that they reduce the dynamical system problems to those of solving a system of algebraic equations. In this talk, a numerical method for solving the delay systems in optimization problems is proposed. The approach is based upon hybrid function approximations. The properties of hybrid functions which consists of block-pulse functions and Bernoulli polynomials are presented. The associated operational matrix of integration is then utilized to reduce the solution of the delay systems to the solution of a system of algebraic equations. The numerical solutions are compared with available exact or approximate solutions in order to assess the accuracy of the proposed method. (Received August 30, 2013)

1096-49-531 **Parimah Kazemi*** (kazemip@beloit.edu), Beloit College, Department of Mathematics, 800 College Street, Beloit, WI 53511, and **Robert Renka**. *A Levenberg-Marquardt method using Sobolev gradients.*

In order to numerically solve nonlinear least squares problems, the Levenberg-Marquardt method presents an attractive option. By combining the Gauss-Newton direction with a gradient descent direction obtained from a Sobolev metric, we obtain a more efficient method for numerical optimization than the traditional Levenberg-Marquardt method gives. We demonstrate this by applying our scheme to numerically find minimizers of the Ginzburg-Landau energy in the presence of a magnetic field. As we treat the optimization problem in the continuous setting, we are able to derive a scheme for obtaining the Levenberg-Marquardt parameter in this setting and thus we do not need to rely on heuristic arguments. (Received September 05, 2013)

1096-49-594 **R. U. Verma*** (r_v124@txstate.edu), **S. Salahuddin** and **A. P. Farajzadeh**.
Generalized Vector Variational Type Inequalities. Preliminary report.

First a generalized class of vector variational type inequalities is introduced, and then applying the Minty's lemma the existence of solutions for the generalized vector variational type inequality problems is established. (Received September 07, 2013)

1096-49-649 **Michael R. Kelly*** (mkelly14@utk.edu) and **Suzanne Lenhart**. *Optimal fishery harvesting on a nonlinear parabolic PDE in a heterogeneous spatial domain.* Preliminary report.

We use the tool of optimal control to investigate harvesting strategies for maximizing yield of a fish population in a heterogeneous, finite domain. We determine whether these solutions include no-take marine reserves as part of the optimal solution. The fishery stock is modeled using a nonlinear, parabolic partial differential equation with logistic growth, movement by diffusion and advection, and with Robin boundary conditions. The objective for the problem is to find the harvest rate that maximizes the discounted yield. Optimal harvesting strategies are found numerically. (Received September 08, 2013)

1096-49-738 **Aden O Ahmed*** (aden.ahmed@tamuk.edu), 700 University BLVD, MSC 172, Kingsville, TX 78363-8202. *Dynamical Game Theory.* Preliminary report.

Dynamical game theory studies conflict problems in systems in which the players' strategies are continuous time quantities. It lies at the intersection of game theory and control theory.

The aim in this preliminary report is to review some basic ideas of this theory. (Received September 09, 2013)

1096-49-802 **Ebrahim Sarabi*** (ebrahim.sarabi@wayne.edu), 4500 cass ave. apt 1110, Detroit, MI 48201, and **Boris Mordukhovich** and **Jiri Outrata**. *Full stability in second-order cone programming.*

The talk presents complete characterizations of Lipschitzian full stability of locally optimal solutions to problems of second-order cone programming (SOCP) expressed entirely in terms of their initial data. These characterizations are obtained via appropriate versions of the quadratic growth and strong second-order sufficient onditions under the corresponding constraint qualifications. We also establish close relationships between full stability of local minimizers for SOCPs and strong regularity of the associated generalized equations at nondegenerate points. Our approach is mainly based on advanced tools of second-order variational analysis and generalized differentiation. (Received September 10, 2013)

1096-49-1050 **Braxton Osting*** (braxton@math.ucla.edu), Department of Mathematics, 520 Portola Plaza, Los Angeles, CA 90095. *Geometric methods for graph partitioning.* Preliminary report.

Several geometric methods for graph partitioning have been introduced in the past few years, with wide applications in clustering, community detection, and image analysis. These methods, which I'll review, are built on graph-based analogues of total variation, motion by mean curvature, the Ginzburg-Landau functional, and the Merriman-Bence-Osher threshold dynamics. In this talk, I'll discuss a new graph partitioning method where the optimality criterion is given by the sum of the Dirichlet eigenvalues of the partition components. The resulting eigenvalue optimization problem can be solved by a rearrangement algorithm, which we show to converge in a finite number of iterations to a local minimum of a relaxed objective function. The method compares well to state-of-the-art approaches when applied to clustering problems on graphs constructed from synthetic data, MNIST handwritten digits, and manifold discretizations. The model has a semi-supervised extension and provides natural representatives for the clusters as well. (Received September 12, 2013)

1096-49-1101 **Robert J Kipka*** (robert.j.kipka@wmich.edu), Robert J. Kipka, 4433 Everett Hall, Western Michigan University, Kalamazoo, MI 49008-5248, and **Yuri S. Ledyaev**. *Optimality Conditions for Problems of Geometric Optimal Control.* Preliminary report.

Techniques of nonsmooth and variational analysis play an important role in problems of optimization and control. It has been demonstrated that such methods provide effective and natural techniques even in problems for which the data is smooth. To this date, however, nonsmooth and variational techniques have not been developed in the context of optimality conditions for control problems posed on manifolds. We present new work in this direction culminating in a new proof of the Pontryagin Maximum Principle under general assumptions. In the process, we demonstrate that nonsmooth costs and constraints can play a natural role in problems with C^∞-smooth costs or constraints and we present a penalization technique which, subject to a certain constraint qualification, permits the replacement of terminal constraints with a nonsmooth penalty function. Finally, we demonstrate that the success or failure of the constraint qualification corresponds to the presence of normal and abnormal extremals, respectively. (Received September 12, 2013)

1096-49-1209 **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 **Mohd Farid**. *Common Solutions to Some Systems of Variational Inequalities and Fixed Point Problems.*

We introduce an iterative scheme for finding a common solution to a new class of systems of unrelated split mixed vector variational inequality problems, multivalued variational inequality problems, and fixed point problems for nonexpansive mappings in a real Hilbert space. We prove that the sequence generated by the proposed iterative scheme converges strongly to a common solution of these systems. Our results extend and generalize previously known results in this area. (Received September 13, 2013)

1096-49-1261 **Gregory Scott Amacher*** (gamacher@vt.edu), 304 D Cheatham Hall, Blacksburg, VA 24060. *The Forest Rotations Problem Under Risk and Uncertainty: Is There Anything Left To Study?*

Not since Faustmann's ground breaking 1849 treatise on the optimal forest rotation has an article been more influential to the field of forest economics than Nobel Laureate Paul Samuelson's lecture and subsequent 1976 Economic Inquiry article, "Economics of Forestry in an Evolving Society." I discuss the development of forest rotations and policy choice modeling since this defining lecture, noting how this line of research has been shaped by Samuelson's article. In many ways he focused attention of critical issues of the time, but this work began a path of research totaling hundreds of papers based on assumptions that landowners solve relatively simple open loop or optimal stopping problems. As such, the field of forest economics is still relatively open especially with regard to relevant questions concerning correlated uncertainties and damages for natural risks that can arrive often more than once during a forest rotation with a landowner who does not automatically harvest after the first event, uncertainty concerning landowner responses in policy instrument choice problems, and the modeling of pure uncertainty in forest rotation problems. I propose some new ways of considering these problems. (Received September 14, 2013)

1096-49-1362 **Marian Bocea*** (mbocea@luc.edu), Loyola University Chicago, Department of Mathematics and Statistics, 1032 W. Sheridan Road, Chicago, IL 60660. *Γ-convergence of inhomogeneous functionals in Orlicz-Sobolev spaces and applications.*

The asymptotic behavior of a class of inhomogeneous functionals is undertaken via Γ-convergence in an Orlicz-Sobolev setting. Some applications to the study of dielectric breakdown are discussed. Joint work with M. Mihăilescu (University of Craiova and "Simion Stoilow" Institute of Mathematics of the Romanian Academy, Bucharest, Romania). (Received September 15, 2013)

1096-49-1365 **Kasie G Farlow*** (kasie.farlow@usma.edu). *A Characterization of the Reflected Quasipotential.* Preliminary report.

Recent interest in the reflected quasipotential comes from the queueing theory literature, specifically the analysis of so-called (b, A, D) reflected Brownian motion where it is the large deviation rate function for the stationary distribution of the (b, A, D) reflected Brownian motion. Our purpose here is to characterize the reflected quasipotential in terms of a first-order Hamilton-Jacobi equation. Because the reflected quasipotential is continuous but not differentiable in general the characterization will be in terms of viscosity solutions. Using conventional dynamic programming ideas, along with a complementarity problem formulation of the effect of the Skorokhod map on absolutely continuous paths, we will derive necessary conditions in the form of viscosity-sense boundary conditions. It turns out that even with these boundary conditions solutions are not unique. In some cases the zero function is also a solution; thus a unique characterization needs to refer to some additional property of the reflected quasipotential. (Received September 16, 2013)

1096-49-1384 **Nicholas O. Kirby*** (nokirby@uw.edu) and **Eliot Fried**. *Γ-limit for inextensible, elastic ribbons having centerlines with nonvanishing curvature.*

In 1930, Sadowsky proposed the limiting form of the energy of an inextensible ribbon of vanishing width. This was based on taking a pointwise limit of the integrand for a ribbon with positive width, where the energy is written as an integral along the centerline of the ribbon. It will be demonstrated that the Γ-limit of an energy functional for an inextensible ribbons with centerlines of nonvanishing curvature yields Sadowsky's proposed functional as the width of the ribbon passes to zero. This is the result of joint work with Eliot Fried. (Received September 15, 2013)

1096-49-1411 **Mau Nam Nguyen***, Fariborz Maseeh Department of Math & Stats, Neuberger Hall, Room 334, 725 SW Harrison St., Portland, OR 97201. *On Lipschitz Properties of Nonsmooth Functions and Set-Valued Mappings via Generalized Differentiation and Applications.*

In this talk, we revisit the Mordukhovich's subdifferential criterion for Lipschitz continuity of nonsmooth functions and coderivative criterion for the Aubin/Lipschitz-like property of set-valued mappings in finite dimensions. The criteria are useful and beautiful results in modern variational analysis showing the state of the art of the field. As an application, we establish necessary and sufficient conditions for Lipschitz continuity of the minimal time function and the scalarization function, that play an important role in many aspects of nonsmooth analysis and optimization.

(This talk is based on joint work with G. Lafferriere) (Received September 15, 2013)

1096-49-1525 **Baasansuren Jadamba**, **Akhtar Khan** and **Miguel Sama*** (msama@ind.uned.es), Calle Juan del Rosal, 12, ETSI Industriales, Madrid, Madrid 28040. *Error estimates for conical regularization of abstract optimization problems.*

In this talk, we deal with an abstract constrained optimization problem in Banach spaces. In this context, by conical regularization we understand those methods which construct a family of approximate problems by replacing the constraint cone by an approximate family of cones. This method is worthwhile in order to get optimality conditions by means of multiplier rules. Recently, we have introduced some variants of these methods by using different families of cones. In particular, in [B. Jadamba, A.A. Khan, M. Sama . (2012). *Regularization for state constrained optimal control problems by half spaces based decoupling*. Systems Control Lett. 61, 707-713] by using a decoupling of the constraint cone into halfspaces and in [A.A. Khan, M. Sama (2013). *A new conical regularization for some optimization and optimal control problems: Convergence analysis and finite element discretization*. Numer. Funct. Anal. Optim. 34, no. 8, 861-895] by using a family of associated Henig dilating cones. In this ocassion, our aim is to measure the distance in norm of the regularized solution to the solution of the original problem by means of a general scheme. And to apply this scheme in order to get numerical error estimates for PDE optimal control problems, (Received September 16, 2013)

1096-49-1596 **Yunho Kim*** (yunho.kim@yale.edu), 300 Cedar Street, TAC, N309, New Haven, CT 06520, and **Hemant Tagare**. *Intensity Non-uniformity Correction Method in MR Imaing.*

We propose a variational method to correct the intensity non-uniformity artifact in the brain MR imaging. Intensity non-uniformity artifact appears in MR imaging due to various reasons such as RF coil inhomogeneity, interactions within the body, etc., which is more prevalent when multiple coils are in use. The underlying structure represented by a piecewise constant function is corrupted by multiplication of a slowly varying function, which results in a piecewise continuous function. Unknown underlying regions, unknown true data values, and noise are what makes it difficult to compensate for the non-uniformity artifact. Under some reasonable conditions, we can prove that a constant multiple of the slowly varying function can be found exactly in a carefully designed set of functions without noise. The minimization problem that we propose extends to the case when noise is present. We will discuss the formulation of the problem and its performances in this talk. As far as we know, no variational approach has been proposed for the problem. (Received September 16, 2013)

1096-49-1649 **Nghia T. A. Tran*** (ttannghia@gmail.com), 1955 Pacific Court, Apt 102, Kelowna, BC V1Y 8B3, Canada. *Coderivative Characterizations of Local Monotonicity with Applications to Variational Systems.*

In this talk we provide various characterizations of local monotonicity in terms of regular and limiting coderivatives, which are new in finite-dimensional and infinite-dimensional frameworks. We also develop effective applications to obtaining Lipschitzian and Holderian continuity of solution maps to conventional models of variational systems and variational conditions in nonlinear programming. (Received September 16, 2013)

1096-49-1667 **Lynn Raburn Greenleaf*** (greenleal@sfasu.edu), Stephen F. Austin State University, Department of Mathematics and Statistics, P.O. Box 13040, SFA Station, Nacogdoches, TX 75962. *Parameter Estimation for Atmospheric Vortices.*

The focus of this talk concerns valid statistical inferences from atmospheric vortex tangential wind measurements on intense atmospheric vortices arising in dust devils, waterspouts, tornadoes and tropical cyclones when the analysis depends on a parametric model of the information in the data. Data analysis is required to demonstrate in an objective way that a parameterized tangential wind model provides an acceptable description of the tangential wind profile of an atmospheric vortex and determine if the model can be used to make accurate predictions Using the methodology of Information Theory and Sensitivity Analysis, information content and uncertainty in radial, tangential and vertical winds were examined and assessed for use in prediction. (Received September 16, 2013)

1096-49-1754 **John Matthews*** (matt-matthews@utc.edu), Dept 6956, 615 McCallie Ave, Chattanooga, TN 37403, and **Boris Belinskiy** and **James W. Hiestand**, Dept 2452, 615 McCallie Ave, Chattanooga, TN 37403. *Effect of convection on optimal design of a bar with attached mass.* Preliminary report.

We minimize the mass of a bar with radial symmetry and a given rate of heat transfer. In engineering, such a construction serves as an extended surface for transfer of heat from an attached mass. Previously, similar work has considered only conduction of heat along the length of the bar. Here we include conduction along the bar as well as convection through the sides, and study bars consisting of multiple pieces with constant cross-sections. The given rate of cooling is defined by the first eigenvalue of the corresponding Sturm-Liouville problem. With convection, the problem is reduced to a set of transcendental equations for the cross-sectional areas. The minimal mass is found through the use of Lagrange multipliers and a Newton-like method. Exact expressions necessary for the optimization are obtained with Maple and the resulting equations are solved within Matlab. The effect of material parameters (including convection) on the optimal solution is studied. (Received September 16, 2013)

1096-49-1759 **Heinz H Bauschke** and **Hung M Phan*** (hungm.phan@yahoo.com), 460 Buckland Ave, Apt.308, Kelowna, BC V1Y5Z4, and **Xianfu Wang**. *Method of Cyclic Relaxed Projections for Nonconvex Systems.* Preliminary report.

The Method of Cyclic Projections (MCP) for systems of sets is a classical algorithm for solving feasibility problems. The Method of Alternating Projections (MAP), a special case of MCP when the system consists only two sets, has recently been intensely studied for nonconvex settings. However, only local convergence results are available: convergence occurs if the starting point is not too far away from solutions. Instead of taking full projection steps, it can be advantageous to underrelax, i.e., to move only part way towards the constraint set, in order to enlarge the regions of convergence. In this paper, we thus study the Method of Cyclic Relaxed Projections (MCRP) for systems of two or more (possibly nonconvex) sets. Complementing recent work on MCP/MAP, we establish local linear convergence results for the MCRP. (Received September 16, 2013)

1096-49-1808 **Mengyi Ying*** (mying1@crimson.ua.edu), University of Alabama, Department of Mathematics, Gordon Palmer Hall, Box 870350, Tuscaloosa, AL 35487, and **Min Sun** (msun@ua.edu), University of Alabama, Department of Mathematics, Gordon Palmer Hall, Box 870350, Tuscaloosa, AL 35487. *Treatment of Single Special Constraint in the Framework of Interval Method for Global Optimization.* Preliminary report.

An interval method is developed for finding optimal solutions of global optimization problem over a bounded interval domain subject to one additional special constraint (such as a linear or quadratic equation or inequality constraint). The main feature of our method is its ability to test any subdomain's feasibility and to locate a feasible point if the feasible set within the subdomain is nonempty. This feature allows our interval method to improve upper bounds of the best objective function value faster than standard interval methods where feasible samples in subdomains are not targeted. The feasibility of our selected samples will be proved and numerical results are provided to demonstrate the effectiveness of this method. (Received September 16, 2013)

1096-49-1867 **Brian C Winkler*** (bcw9368@rit.edu). *Gradient and Extragradient Methods for Elliptic Inverse Problems with an Application to the Tumor Identification Problem.* Preliminary report.

This talk examines the application and comparison of gradient-based and extragradient methods for the solution of elliptic inverse problems within a general optimization framework. We consider the application of these methods to a particular inverse problem in linear elasticity: identifying tumor locations within the soft tissue of the human body. Detailed implementation issues will be covered along with thorough performance analyses for a variety of methods and differing approaches, including the output least squares (OLS) and modified output least squares (MOLS) functionals. The results of several numerical experiments showing the recovery of variable parameters will also be presented. (Received September 16, 2013)

1096-49-1967 **Weihong Guo*** (wxg49@case.edu), 10900 Euclid Avenue, Cleveland, OH 44106, **Jing Qin**, 520 Portola Plaza, Los Angeles, CA 90095, and **Wotao Yin** (wotaoyin@ucla.edu), 520 Portola Plaza, Los Angeles, CA 90095. *A New Detail-preserving Regularity Scheme.*

It is a challenging task to reconstruct images from their noisy, blurry, and/or incomplete measurements,especially those with important details and features such as medical MR and CT images. We propose a novel regularization model that integrates two recently-developed regularization tools: total generalized variation (TGV) by Bredies, Kunisch, and Pock; and shearlet transform by Labate, Lim, Kutyniok, and Weiss. The proposed model recovers both edges and details of images much better than the existing regularization models based on the total variation (TV) and wavelets. Specifically, TGV preserves sharp edges as TV but does not have oil-painting artifacts of TV. Shearlets can efficiently represent anisotropic features such as edges and curves that wavelets cannot.

The proposed model has been tested in the compressive sensing reconstruction context and produced high-quality images using fewer measurements than the state-of-the-art methods. (Received September 16, 2013)

1096-49-2054 **Narayan Thapa*** (narayan.thapa@minotstateu.edu). *Existence and Uniqueness of Solution of Second Order Hyperbolic Partial Differential Equation with Point Effect.*

In this talk we consider second order hyperbolic partial differential equation. Priori estimates is used to show existence of weak solution. Uniqueness of the weak solution is established. (Received September 17, 2013)

1096-49-2095 **Monica Gabriela Cojocaru***, 50 Stone Road East, Department of Mathematics & Statistics, Guelph, ON N1G 2W1, Canada. *Solving generalized Nash games with shared constraints through evolutionary variational inequalities.*

We show in this talk how a new parametrization technique can be introduced via the so-called evolutionary variational inequality (EVI) problems, such that by restricting the solution sets of such specialized EVI problems, together with complementarity conditions, we obtain a clear description of the solution set of a generalized Nash (GN) game with shared constraints. As a consequence, the stability of GN equilibria can be studied. We give examples of how the technique is used and show that it solves GN previously not solved by existing VI parametrization techniques. (Received September 17, 2013)

1096-49-2300 **Erin R. Crossen*** (erc7690@rit.edu), 1198 Judge Rd, Basom, NY 14013. *An Equation Error Approach for the Elasticity Imaging Inverse Problem for Predicting Tumor Location.* Preliminary report.

The primary objective of this work is to study the elasticity imaging inverse problem of identifying cancerous tumors in the human body. This nonlinear inverse problem not only represents an important and interesting application, it also brings forth noteworthy mathematical challenges since the underlying model is a system of elasticity equations involving incompressibility. Due to the locking effect, classical finite element methods are not effective for incompressible elasticity equations. Therefore, special treatment is necessary for both the direct and inverse problems. To study the inverse problem in an optimization framework, we propose an extension of the equation error approach. We focus on two cases, namely when the material parameter is sufficiently smooth and when it is may be discontinuous. For the latter case, we extend the total variation regularization method to the elasticity imaging inverse problem. We give existence results for the proposed equation error approach and give convergence analysis for the discretized problem. We give sufficient details on the discrete formulas as well as on the implementation issues. Numerical examples for smooth and discontinuous coefficients are given (Received September 17, 2013)

1096-49-2350 **Julia Eaton*** (jreaton@uw.edu) and **Michael Overton**. *Optimal solutions to a root minimization problem over a polynomial family with two constraints.* Preliminary report.

Consider the system $y' = A(x)y$, where A depends 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 17, 2013)

1096-49-2416 **M Zuhair Nashed*** (zuhair.nashed@ucf.edu). *Concepts of Differentiability in Smooth and Non-smooth Analysis with Applications in Optimization Theory and Algorithms.* Preliminary report.

In this talk I will provide an overview of several concepts of differentiability in smooth, semi-smooth and non-smooth analysis. Applications in optimization theory and algorithms and nonlinear integral equations will be presented. (Received September 17, 2013)

1096-49-2448 **Hem Raj Joshi***, joshi@xavier.edu. *Optimal Control of SIR Model with Education.* Preliminary report.

We develop an optimal control model of Susceptibles, Infected and Recovered (SIR) type. In this model, the control is education, which helps to change behaviors of the susceptible class and this class contributes to lower the infected and thus recovered/removed population. We determine the steady states and do a stability analysis, solve an optimal control problem with the objective function that minimizes the infected population, and maximizes the susceptible population. We solved optimality system numerically using Runge Kutta method. (Received September 17, 2013)

1096-49-2502 **C. Nahak*** (cnahak@maths.iitkgp.ernet.in), Department of Mathematics, Indian Institute of Technology Kharagpur, Kharagpur, WestBengal 721302, India. *Regularized Gap Function for Optimization Problems in Banach Spaces.*

By using the regularized gap function for variational inequalities, Li and Peng introduced a new penalty function $P_a(x)$ for a constrained minimization problem on R^n. Under certain assumptions, they proved that the original constrained minimization problem is equivalent to unconstrained minimization of $P_a(x)$. Later Li and Nahak gave an in-depth study of those properties of the objective function that can be extended from the feasible set to the whole R^n by $P_a(x)$. The main purpose of this paper is to define $P_a(x)$ on constrained minimization problems on Banach space X and study those properties which can be extended from feasible set to the whole of X. The convexity of the objective function does not imply the convexity of $P_a(x)$ when the objective function is not quadratic, no matter how small a is. Instead, the convexity of the objective function on the feasible set only implies the invexity of $P_a(x)$ on X. Moreover, a characterization for the invexity and pseudo-invexity of $P_a(x)$ is also given. (Received September 17, 2013)

1096-49-2505 **Baasansuren Jadamba*** (bxjsma@rit.edu), Rochester, NY 14623, and **Fabio Raciti**. *On the Modeling of Some Environmental Games with Uncertain Data.*

We deal with a class of environmental games where the data are affected by uncertainty and are given through their probability distributions. Our investigation is performed in the framework of variational inequalities in Lebesgue spaces. (Received September 17, 2013)

1096-49-2551 **Akhtar A Khan***, School of Mathematical Sciences, Rochester Institute of Technology, Rochester, NY 14623. *On Multi-valued Quasi Variational Inequalities.* Preliminary report.

This talk will focus on some existence results and regularization methods for multi-valued quasi variational inequalities. (Received September 17, 2013)

1096-49-2554 **Corinne Teravainen***, School of Mathematical Sciences, Rochester, NY 14623. *Continuous Newton Method for Elliptic Inverse Problems.*

This talk will focus on a numerical approach of using continuous Newton method for the inverse problem of identifying a variable parameter in elliptic inverse problems. (Received September 17, 2013)

1096-49-2599 **Alvaro Cartea**, **Sebastian Jaimungal** and **Damir Kinzebulatov*** (dkinzebu@fields.utoronto.ca). *Algorithmic trading with learning: informed versus uninformed.*

A high-frequency trader takes a view on the market, and then acts accordingly: buys an asset if she predicts an upward trend in asset's mid-price, or sells the asset if she predicts a downward trend. However, if she is not fully confident in her prediction, how can she optimally trade?

In the present paper we develop a framework to address this problem. We model the mid-price by a randomized Brownian bridge. At terminal time it is a pre-specified random variable that encodes the trader's prior estimate of the asset's future mid-price distribution, e.g. a discrete random variable taking two values corresponding to upward/downward trends. In the latter case the optimal trading strategy 'learns' from the dynamics of the mid-price whose trend is being realized on the market.

We analyze various features of trader's optimal strategy, dynamics of her inventory and book value, risk-return profiles. We also compare the performance of optimal strategies of three traders who differ in accuracy of their predictions of the real world distribution of the mid-price. (Received September 17, 2013)

1096-49-2622 **Ahad Dehghani*** (ahad.dehghani@mcgill.ca), , Canada, and **Jean-Louis Goffin** and **Dominique Orban**. *On Handling Free Variables in Semidefinite Programming Using a Primal-Dual Regularized Interior-Point Method.*

Interior-point methods in semidefinite programming (SDP) require the solution of a sequence of linear systems which are used to derive the search directions. Safeguards are typically required in order to handle rank-deficient Jacobians and free variables. We propose a primal-dual regularization to the original SDP and show that it is possible to recover an optimal solution of the original SDP via inaccurate solves of a sequence of regularized SDPs for both the NT and dual HKM directions. This work is a generalization of recent work by Friedlander and Orban for quadratic programming. (Received September 17, 2013)

51 ► Geometry

1096-51-156 **Paul Gallagher**, **David Hu**, **Zane Martin**, **Maggie Miller*** (mhmiller@math.utexas.edu) and **Byron Perpetua**. *Convex Region Isoperimetric Conjecture.* Preliminary report.

We study the Convex Body Isoperimetric Conjecture in the plane, which states that it takes more perimeter to enclose given area in a unit-area disk than in any other unit-area convex region. This conjecture has been proved for area 1/2 by Esposito *et al.* in 2012 and for small area with certain restrictions by Gallagher *et al.* in 2013. (Received August 10, 2013)

1096-51-242 **David A. Herron** and **Poranee K. Julian*** (julianpk@ucmail.uc.edu). *Blaschke's Rolling Ball Property and Conformal Metric Ratios.*

This research is focused on a generalization of Blaschke's Rolling Ball Property that has been used to study various problems from mathematical morphology, image analysis, and smoothing. The purpose of this work was to characterize the closed sets in Euclidean space that satisfy a two-sided rolling ball property and to show that certain conformal metric ratios have a boundary value of one as an application. A closed set satisfies the two-sided rolling ball property provided it is possible to freely roll a ball with fixed radius inside and outside the closed set along its boundary. The main theorem proved by a geometric approach can be summarized as follows:

A non-empty and closed set has the two-sided rolling ball property if and only if it is an orientable $C^{1,1}$ smooth embedded submanifold, and there is a globally defined Lipschitz continuous unit normal vector field along it.

The size of a singular set was also studied in this work. Here, the singular set for a C^1 hypersurface is the set of points where the associated unit normal vector field is not differentiable. (Received August 22, 2013)

1096-51-254 **J Mealy*** (jmealy@austincollege.edu), Austin College, suite 61560, 900 North Grand Avenue, Sherman, TX 75090, and **Kusha Mohammadi**. *Staircase metrics in space-time geometries.*

After a brief introduction to this general category of systems with staircase-function metrics (formerly, 'Snell geometry') and its natural methodology (which contrasts considerably with that of differential geometry), we discuss an extension of the scheme to space-time geometries. Focusing on systems where the underlying parameter space is the 2-plane, we establish metrics and derive formulas that lead to straightforward constructions of a large variety of semi-complete (or complete) time-like geodesics. These can be used, for example, to construct fully time-like asymptotic polygons. We demonstrate the construction of such complete geodesics via two sub-cases; the latter sub-case essentially entails 'staircase versions' of general (1,1)-FLRW (Robertson-Walker) metrics in general relativity. (Received August 23, 2013)

1096-51-296 **Mikael Vejdemo-Johansson*** (mikael@johanssons.org) and **Anders Sandberg**. *Extending existing enumerations: on the mathematics of tie knots.* Preliminary report.

Tying a necktie may for some be the main if not only regularly occurring fiber arts activity they participate in. A chore for some, space for personal expression for others, the necktie used to have very few specific knots in widespread use. In their 1999 paper, Fink & Mao ("Designing tie knots by random walks." Nature 398, no. 6722 (1999): 31-32) enumerate all possible ways to tie a necktie. They limit their enumeration task by focusing on knots that present a flat front just like all the classical tie knots. They establish a list of 85 possible tie knots.

Tie knots with intricate patterns of the necktie winding into symmetric but no longer flat front displays have emerged in the past decade, introduced by the movie *Matrix Reloaded* and recreated hobbyists. These tie knots are tied with the narrow end of the tie, wrapping it to create patterns on the surface of the tie knot. As such these knots are not covered by the enumeration proposed by Fink & Mao.

We extend Fink & Mao's enumeration to include the various tie knots proposed in the reconstruction of the movie tie knot: these too can be captured by a formal language, and we can prove simplifications of Fink & Mao's original language that simplify the extension and analysis of all tie knots. (Received September 02, 2013)

1096-51-324 **Tengren Zhang*** (tengren@umich.edu). *Degeneration of convex projective structures on surfaces.* Preliminary report.

Let S be a closed surface and let C(S) be the space of convex projective structures on S. Choi-Goldman showed that C(S) is the Hitchin component of representations of the fundamental group of S to SL(3,R). This space was also studied and generalized by Benoist to convex projective structures on closed orbifolds. I will present new results about how some of the geometric properties of the convex projective structure degenerate as one deforms the structure along the internal parameters of the Goldman parameterization of C(S). The geometric properties considered here include the lengths of closed curves, the Hilbert volume, the maximal injectivity radius, and the topological entropy of the (Hilbert) geodesic flow. (Received August 28, 2013)

1096-51-379 **Joshua Brandon Holden*** (holden@rose-hulman.edu), Department of Mathematics, Rose-Hulman Institute of Technology, Terre Haute, IN 47803. *Granny's Not So Square, After All: Hyperbolic Tilings with Truly Hyperbolic Crochet Motifs.*

Until now, most methods for making a hyperbolic plane from crochet or similar fabrics have fallen into one of two categories. In one type, the work starts from a point or line and expands in a sequence of increasingly long rows, creating a constant negative curvature. In the other, polygonal tiles are created out of a more or less Euclidean fabric and then attached in such a way that the final product approximates a hyperbolic plane on the large scale with an average negative curvature. On the small scale, however, the curvature of the fabric will be closer to zero near the center of the tiles and more negative near the vertices and edges, depending on the amount of stretch in the fabric. The goal of this project is to show how crochet can be used to create polygonal tiles which themselves have constant negative curvature and can therefore be joined into a large region of a hyperbolic plane without significant stretching. Formulas from hyperbolic trigonometry are used to show how, in theory, any regular tiling of the hyperbolic plane can be produced in this way. (Received August 31, 2013)

1096-51-440 **Assaf Naor*** (naor@cims.nyu.edu), 251 Mercer Street, New York, NY 10012. *Super-expanders.*

A bounded degree n-vertex graph $G = (V, E)$ is an expander if and only if for every choice of n vectors $\{x_v\}_{v\in V}$ in $\mathbb{R}^k$ the average of the Euclidean distance between x_u and x_v is within a constant factor of the average of the same terms over those pairs $\{u, v\}$ that form an edge in E. The fact that this property is equivalent to the usual combinatorial notion of graph expansion is very simple to prove, and once stated, it is obvious to ask what happens when $\mathbb{R}^k$ is replaced by other metric spaces. It turns out that this is a subtle question that relates to a long line of investigations in analysis and geometry. Graphs that are expanders in the classical sense (including random graphs) may or may not be expanders with respect to certain non-Euclidean geometries of interest. Existence of such "metric" expanders becomes a delicate question due in part to the fact that the existing combinatorial, probabilistic and spectral methods that are used for the purpose of constructing classical expanders are insufficient in the metric setting. In this talk we will formulate some of the basic questions in this direction, and explain some of the ideas and methods that were introduced in order to address them. (Received September 03, 2013)

1096-51-517 **Tara D Taylor*** (ttaylor@stfx.ca), Department of Mathematics, Statistics and CS, St. Francis Xavier University, Antigonish, NS B2G 2W5, Canada. *Totally Disconnected Sierpiński Relatives.*

This talk presents an investigation of various ways to characterize and classify the class of fractals that are the totally disconnected Sierpiński relatives. While the fractals in this class all have the same fractal dimension, and the same topologies, there are several ways to distinguish sub-classes of the relatives and to highlight the richness of the structures of these fractals. One method involves the use of ϵ-hulls. (Received September 05, 2013)

1096-51-557 **Khoa Lu Nguyen***, 450 Serra Mall, Building 380, Stanford, CA 94305. *On SFT invariants of the complements of ample normal crossing divisors in projective varieties.* Preliminary report.

In this talk, I will describe work in progress how SFT invariants (e.g. linearized contact homology, symplectic homology) of the complement of ample divisors in a projective variety changes as the divisor degenerates into a normal crossing divisor. I will mainly focus on the case complex dimension equal to 2. If time permits, I will mention how it can be potentially generalized to higher dimension. (Received September 06, 2013)

1096-51-607 **Tarik Aougab*** (tarik.aougab@yale.edu), Yale University Mathematics Department, 10 Hillhouse Avenue, New Haven, CT 06511. *Minimal length, minimally intersecting filling pairs over Moduli space.*

(Topological) Morse functions defined over the moduli space of Riemann surfaces have been extensively studied; understanding the structure of the critical points of such a function can give rise to naturally occurring cellular decompositions of moduli space. One such function is the systole function, which, given a hyperbolic surface, outputs the length of the shortest closed geodesic. We propose and analyze a different sort of systole function: one which outputs the length of the shortest pair of simple closed curves which fill the surface, and which intersect minimally amongst all filling pairs. We completely characterize the minima of this function, and we compute lower and upper bounds for the number of global minima; in particular, there are at least exponentially many as a function of genus. Furthermore, there exists some uniform constant K such that all minima are in the K-thick part, independent of genus. This is joint work with S. Huang. (Received September 07, 2013)

1096-51-626 **Ved V Datar*** (veddatar@math.rutgers.edu). *Conical soliton metrics on Kähler manifolds.*

Recently there has been a lot of interest in conical metrics on Kähler manifolds, culminating in the resolution of the Yau-Tian-Donaldson conjecture last year. In this talk, we first give criteria for the existence of conical Kähler-Einstein metrics (KE) and Kahler-Ricci solitons (KRS) on toric manifolds, in relation to the greatest Ricci and Bakry-Emery Ricci lower bound. We then describe how to connect any two toric manifolds of the same dimension by a continuous path of toric manifolds with conical KE metrics. We end by relating the greatest Bakry-Emry Ricci lower bound on general Fano manifolds to the continuity method for solving the KRS equation. (Received September 08, 2013)

1096-51-689 **Jane Gilman*** (gilman@rutgers.edu) and **Linda Keen**. *The Hyperbolic Geometry of* $\mathbb{H}^3$ *Hexagons and* $PSL(2,\mathbb{C})$ *Discreteness Sequences.* Preliminary report.

A subgroup, G, of $PSL(2,\mathbb{C})$ is not discrete if there exists an infinite sequence of distinct elements of the group that converges to the identity. However, there are only ad hoc techniques for finding such a sequence of primitive elements in any given G. If ρ is a non-elementary representation of a rank two free group, F, into $PSL(2,\mathbb{C})$, its image, $\rho(F) = G$, may or may not be discrete or free. However, in all cases there is an ordering of the rational numbers determined by the representation. We call this the *representation ordering*. We use the hyperbolic geometry of $\mathbb{H}^3$ as applied to certain palindromes in G and the representation ordering of the rationals to construct a unique sequence of primitive elements corresponding to a given representation. The conjecture is that this sequence, termed the *core sequence*, will converge to the identity if the group is not discrete, will be finite in the case that the group is discrete with rational pleating locus and will be infinite but the corresponding geodesics will converge in the interior if the group is discrete with irrational pleating locus. We have a conjectural picture of the *stopping hexagons* when the sequence is finite. (Received September 09, 2013)

1096-51-703 **Derege H Mussa***, Department of mathematics, Texas A&M University -Commerce, 75429-3011, Commerce, TX 75429. *Tetrahedron and Nets.* Preliminary report.

Given six stick lengths, even if any triple of these lengths satisfy the (strict) triangle inequality (the sum of the lengths of any two sticks is greater than the third), there may be no tetrahedron with edges having these six length . A tetrahedron is a three dimensional solid having four vertices , four triangular faces and six edges which don't lie in a single plane.a six tuple =(a, b, c, d ,e, f) exists if its facial and the McCrean determinant is positive. A net can be described as the polygon obtained when one cuts along a spanning tree of a (convex) polyhedron so that the polyhedron can be opened into a simple plane polygon. When cuts along a spanning tree results in a self-intersecting plane polygon the result will be called an overlapping net. This leads to the following open problem:Does every tetrahedron have a path net with a none overlapping unfolding? It is important to emphasize that for a tetrahedral it is not particularly easy to find edge lengths and a spanning tree for which this phenomenon occurs. there can be a spanning tree for a tetrahedron which when cut will lead to a way to open up the tetrahedron which will overlap.In response to a conjecture (Fukuda) example have been found for the partition. (Received September 09, 2013)

1096-51-816 **Babak Modami***, UIUC, Department of Mathematics, 1409 West Green ST, Urbana, IL 61801. *Symbolic coding of Weil-Petersson geodesic flow.*

The Weil-Petersson (WP) geodesic flow is a non-uniformly hyperbolic flow on the moduli space of Riemann surfaces. We review some of Brock-Masur-Minsky and ourselves results toward developing a kind of symbolic coding of WP geodesic flow in terms of laminations and associated subsurface coefficients. Then we focus on our recent work which as a result provides for recurrent WP geodesics to the thick part of moduli space with non-uniquely ergodic ending lamination. This is in contrast with Masur's criterion for Teichmuller geodesics. (Received September 10, 2013)

1096-51-949 **Brian Mann*** (mann@math.utah.edu). *Hyperbolicity of the Cyclic Splitting Complex.*

The outer automorphism group of a free group is defined to be the group of all automorphisms modulo those given by conjugation, and is denoted $Out(F_n)$ for a free group of rank n. To study this group, we define a new complex on which $Out(F_n)$ acts by simplicial automorphisms, the cyclic splitting complex of F_n, and show that it is hyperbolic using a method developed by Kapovich and Rafi. (Received September 11, 2013)

1096-51-957 **Cindy Grimm***, 204 Rogers Hall, Dept. of Mech. Eng, OSU, Corvallis, OR 97331, and **Sandra Rugonyi** and **Rolf Mueller**. *Shape correspondence for biological applications.* Preliminary report.

Shape and function are intricately related in biology. We present three biological case studies where the goal is to quantify shape change in order to analyze how shape informs function. We will highlight the challenges in analyzing these data sets in the context of the relevant biological applications, and describe shape correspondence techniques developed to handle them.

Case study 1: Using strain to track ferret brain development. Case study 2: Using geodesic distances and an approximate medial axis to track an in-vivo beating chicken heart (peristaltic motion). Case study 3: Shape space based on natural neighbor coordinates for defining bat pinnae and noseleaves. (Received September 11, 2013)

1096-51-1056 **Todd A. Drumm*** (tdrumm@howard.edu) and **Virginie Charette**. *Uniqueness of Bidisk Bisectors.*

The bidisk, $H^2 \times H^2$, is a fascinating rank 2 geometry. In an earlier paper, the coauthors showed that for hyperbolic-hyperbolic cyclic groups the Dirichlet domain centered on the *axis* was bounded by two disjoint bisectors, that is equidistant hypersurfaces. Examples where the Dirichlet domain was bounded by pieces of more than two bisectors , which intersected, were also constructed. These two phenomena are reminiscent of the situation in H^3. In this talk, we will show how the bidisk is strikingly different than H^3, by showing that no two different pairs of points can have the same bisector. (Received September 12, 2013)

1096-51-1182 **Pamela Lowry*** (plowry@ltu.edu), 21000 W. Ten Mile Road, Southfield, MI 48075-1058. *Investigating Strategies when designing Geometry in Art as an Online Course, student's attitudes, and achievement.* Preliminary report.

Geometry in Art course includes symmetry and tiling, solids and golden ratio, perspective, surfaces and motion, etc. In each part of the course underlying mathematical principles relating to different aspects of art and architecture are explored. Different strategies need to be considered carefully when developing this course online. Technologies need to be considered to ensure that the course is as effective online as it would be in a face-to-face or hybrid format. Issues and strategies need to be considered concerning how students and instructors interact with these technologies and how they influence teaching and learning. Such strategies include helping students visualize concepts such as symmetry or perspective, how projects will be administered which include individual and group projects, getting permission to utilize chapters in different textbooks, being creative concerning field trips, and getting permission to view movies at no cost to students. It is equally important to make sure you are not using technology just for the sake of using it. It is important to build confidence in the learner's use of the technology which can engage students and improve their learning. (Received September 13, 2013)

1096-51-1246 **Kyle Evitts*** (kyle.evitts@linfield.edu), **Brian Whetter** and **Brian Keating**. *Tilings of Annular Regions.*

In this talk we discuss our results from the Willamette Valley REU program this summer where we investigated tiling questions in the integer lattice. The most basic question is, given a connected region R made up of unit cells and a set of polyomino tiles T, can one cover R using tiles from T so that each cell in R is covered once and only once? A lot is already known about tilings of simply connected regions, so we studied tilings of rectangular annular regions over the set of T and skew tetrominoes. We give a complete classification of which annular regions are tileable. However, the goal of this talk will be to present our enumeration of possible tilings for a subset of the regions we studied. (Received September 13, 2013)

1096-51-1371 **Son Lam Ho*** (sonlam@math.umd.edu), 9242 E Parkhill Dr, Bethesda, MD 20814. *On conformally flat circle bundles over surfaces.*

we will present an introduction to flat conformal geometry of the 3-sphere, with the focus on 3-manifolds modeled on this geometry that are circle bundles over closed surfaces. The talk will recall conjecture by Gromov-Lawson-Thurston and present our recent partial result towards this conjecture. (Received September 15, 2013)

1096-51-1426 **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. *Transition in the Fractal Geometry of Arctic Melt Ponds.*

During the Arctic melt season, the sea ice surface undergoes a remarkable transformation from vast expanses of snow covered ice to complex mosaics of ice and melt ponds. Sea ice reflectance or albedo, a key parameter in climate modeling, is largely determined by the complex evolution of melt pond configurations. In fact, ice–albedo feedback has played a major role in the recent declines of the summer Arctic sea ice pack. However, understanding melt pond evolution remains a significant challenge to improving climate projections. Here we will discuss recent findings on the evolution of melt pond geometry. In particular, we have found that as the ponds grow and coalesce, their fractal dimension undergoes a transition from 1 to about 2, around a critical length scale of 100 square meters in area. As the ponds evolve they take complex, self-similar shapes with boundaries resembling space-filling curves. We will also discuss how mathematical models of composite materials and statistical physics, such as percolation and Ising models, are being developed to describe this evolution. (Received September 15, 2013)

1096-51-1509 **Terence D Long*** (tlong271@math.umd.edu). *Twist-bulge derivatives and deformations of convex real projective structures on surfaces.*

We study properly convex real projective structures on closed surfaces. A starting point is the Fenchel-Nielsen-type parametrization of Goldman for the deformation space of properly convex real projective structures, which involves a generalization of Fenchel-Nielsen twists - the projective "twist-bulge" deformation. Using the results of Labourie and Fock-Goncharov on the flag curve associated to an Anosov representation, we derive a PSL(3,R) analog for results of Wolpert concerning twist-length derivatives in the case of Teichmueller space. (Received September 16, 2013)

1096-51-1576 **Gabriel D Kerr*** (gdkerr@math.ksu.edu), Mathematics Department, 138 Cardwell Hall, Manhattan, KS 66506. *Tropical Morse functions and their homological mirrors.*

The homological mirror symmetry conjecture applies to a wide range of algebraic varieties. In this talk, I will discuss the conjecture for a complete n-dimensional toric variety X. The conjecture in this case equates the derived category of coherent sheaves on X with the Fukaya-Seidel category $FS(W)$ of a Landau-Ginzburg (LG) model $W : (\mathbb{C}^*)^n \to \mathbb{C}$. By studying a tropical version of the LG model, I will show how $FS(W)$ can be decomposed into several basic categories. Each of these categories arises from passing through the tropical version of a Morse critical point. I will conclude with a discussion of the mirror to this decomposition which is the semi-orthogonal decomposition of $D^b(X)$ arising from a minimal model run. (Received September 16, 2013)

1096-51-1593 **Alexander Dranishnikov*** (dranish@math.ufl.edu), Department of Mathematics, University of Florida, 358 Little Hall, Gainesville, FL 32611-8105. *Asymptotic dimension with control.*

The asymptotic dimension with control was defined by Gromov to study finitely generated groups. In my talk I plan to discuss some open problems related to this concept. (Received September 16, 2013)

1096-51-1839 **Jonah B Gaster*** (jbgaster@gmail.com), University of Illinois at Chicago, 322 Science and Engineering Offices (M/C 249), 851 S. Morgan Street, Chicago, IL 60607-7045. *A family of non-injective skinning maps with critical points.*

Following Thurston, certain classes of 3-manifolds yield holomorphic maps on the Teichmüller spaces of their boundary components. Inspired by numerical evidence of Kent and Dumas, we present a negative result about these maps. Namely, we construct a path of deformations of the hyperbolic structure on a genus-2 handlebody with two rank-1 cusps. We exploit an orientation-reversing isometry to conclude that the skinning map sends a specified path to itself, and use estimates on extremal length functions to show non-monotonicity and the existence of a critical point. Time permitting, we will indicate some surprising unexplained symmetry that comes out of our calculations. (Received September 16, 2013)

1096-51-2010 **Courtney M. Page-Bottorff*** (cpagebot@asu.edu), 9464 E. Los Lagos Vista Ave., Mesa, AZ 85209. *Computations on Parametrized Surfaces with Chebfun2.*

Chebfun is a collection of algorithms and an open-source software system in object-oriented MATLAB that extends familiar powerful methods of numerical computation involving numbers to continuous or piecewise-continuous functions. The success of this strategy is based on the mathematical fact that smooth functions can be represented very efficiently by polynomial interpolation at Chebyshev points. More recently, the system has been extended to handle bivariate functions and vector fields. These two new classes of objects are called Chebfun2 and Chebfun2v respectively. In this talk, we show that Chebfun2 and Chebfun2v can be used to accurately and efficiently perform various computations on parametric surfaces in two or three dimensions, including path trajectories and mean and Gaussian curvatures. More advanced surface computations such as mean curvature flows are also explored. (Received September 17, 2013)

1096-51-2282 **Zachary Abel** (zabel@math.mit.edu), **Thomas Hull*** (thull@wne.edu) and **Tomohiro Tachi** (tachi@idea.c.u-tokyo.ac.jp). *An origami locked triangular mesh in $\mathbb{R}^3$.*

We present a piecewise isometric immersion of a bounded region of $\mathbb{R}^2$ into $\mathbb{R}^3$ (i.e., an origami fold) that is non-flat (the image does not lie in a plane, or more precisely the immersion is injective), is triangular (the maximal isometric regions in the immersion are all triangles), and locked (the folded image cannot be rigidly unfolded back to a flat plane). Such immersions were previously not known to exist and are of interest in architecture and industrial design. (Received September 17, 2013)

1096-51-2285 **Przemyslaw Prusinkiewicz*** (pwp@cpsc.ucalgary.ca), Department of Computer Science, University of Calgary, 2500 University Dr. N.W., Calgary, Alberta T2N 1N4, Canada. *Constraints of space in plant development: Where fractal forms come from?*

Like all forms in nature, plants are subject to the properties of space in which they are embedded. On the one hand, space prevents configurations that would place more than one component in the same location at the same time. A generalization of this constraint limits proximity and density of organs. On the other hand, space provides a means for a plant to create three-dimensional forms by differentially controlling their growth. This results from a connection between the metric properties of surfaces and their curvature. Three strategies are used by plants to develop within the constraints of space: expansion to another dimension, egalitarian partitioning of space, and competition for space. Each of these strategies is closely related to the emergence of fractal forms. They will be illustrated with the examples of curved surfaces of leaves and petals, self-similar branching structures of compound leaves and inflorescences, and tree architectures. The examples highlight the fundamental role of the constraints of space in plant development, and the complementary role of genetic regulation and space-dependent emergent phenomena in shaping a plant. (Received September 17, 2013)

1096-51-2453 **Russell M Ricks*** (rmricks@umich.edu), Mathematics, 2074 East Hall, Ann Arbor, MI 48109-1043. *Almost Hyperbolic—Flat Strips are "Rare" in Rank One CAT(0) Spaces.*

Let X be a proper, geodesically complete CAT(0) space and Γ be a group acting properly discontinuously, cocompactly, and by isometries on X; further assume X admits a rank one axis. We will discuss how to place a natural measure (called the Patterson-Sullivan measure) on the boundary of X, and another (called the Bowen-Margulis measure) on the space of geodesics in X modulo the Γ-action. This additional structure allows us to prove two results about X. First, with respect to the Patterson-Sullivan measure, almost every point in the boundary of X is isolated in the Tits metric. Second, under the Bowen-Margulis measure, almost no geodesic bounds a flat strip of any positive width. (Received September 17, 2013)

1096-51-2644 **Caleb J. Ashley*** (caleb.j.ashley@howard.edu). *Toward a discreteness algorithm for rank 3 non-elementary subgroups of $PSL(2, R)$.*

Let Γ be a rank 3 non-elementary subgroup of $PSL(2, R)$. The motivation for this talk is the pursuit of sufficient conditions for a discreteness algorithm for the subgroup Γ. A discreteness algorithm for Γ generated by 3 parabolic elements is presented. (Received September 17, 2013)

1096-51-2750 **Cindy Grimm*** (cindy.grimm@oregonstate.edu), 204 Rogers Hall, Dept. of Mech. Eng, OSU, Corvallis, OR 97331, and **Ruth West**, **Tao Ju**, **Michelle Vaughan** and **Ross Sowell**. *Open questions in user-guided manual 3D image segmentation.* Preliminary report.

Manual segmentation of 3D volume data is still one of the most common ways to produce surfaces of biological structures. This is a time-consuming process that relies on human perception and domain knowledge. Current practices are based largely on an artifact of old 3D image acquisition systems, where in-plane resolution was much higher than inter-plane resolution. This led to manual contouring on a slice-by-slice basis, and subsequent stitching together together of the contours to create a surface.

More recent approaches look at the problem of reconstructing from oblique contours. This has the potential to reduce the number of manual contours needed, but leads to interesting questions such as: Can people segment with oblique contours? How many contours are needed? Where should they be placed? If you know the topology of the surface, how can you incorporate this knowledge into the surfacing and contouring algorithms? How do you merge sets of contours? Can you use partial contours?

I will describe a recently developed user interface, Volume Viewer, for creating oblique contours and discuss the implications and open problems for creating surfaces from these oblique contours. (Received September 18, 2013)

1096-51-2766 **Ingrid Daubechies***, Department of Mathematics, 120 Science Dr, Durham, NC 27708.
Distances between surfaces, with biological applications.

The talk describes new distances between pairs of two-dimensional surfaces (embedded in three-dimensional space) that use both local structures and global information in the surfaces. This is work done by a collaboration of mathematicians, computer scientists and biologists.

These are motivated by the need of biological morphologists to compare different phenotypical structures. At present, scientists using physical traits to study evolutionary relationships among living and extinct animals analyze data extracted from carefully defined anatomical correspondence points (landmarks). Identifying and recording these landmarks is time consuming and can be done accurately only by trained morphologists. This necessity renders these studies inaccessible to non-morphologists and causes phenomics to lag behind genomics in elucidating evolutionary patterns.

We develop an approach that does not require any preliminary marking of special features or landmarks by the user, and that leads to fast implementation for pairwise comparison of surfaces. (Received September 25, 2013)

52 ► Convex and discrete geometry

1096-52-141 **Lori Beth Ziegelmeier*** (lziegel1@macalester.edu), 1600 Grand Avenue, St. Paul, MN 55105, and **Michael Kirby** and **Chris Peterson**. *A Quadratic Program to Stratify High Dimensional Data Based on Proximity to the Convex Hull.*

The convex hull of a set of points, C, in Euclidean space can help expose extremal properties of C and can help identify elements of C of high interest. We propose a quadratic program for the purpose of stratifying points in a data cloud based on proximity to the convex hull. A quadratic program is solved for each data point to determine an associated weight vector. We show that the weight vector encodes geometric information concerning the point's relationship to the boundary of the convex hull. For instance, we observe that the ℓ_2-norm of the weight vector is a measure of the distance of the associated point from the boundary. By adjusting parameters in the quadratic program, the weight vector can be made to contain negative components if and only if the point is a vertex. The computation of the weight vectors can be carried out in parallel and the overall computational complexity of the algorithm grows linearly with dimension. As a consequence, meaningful computations can be completed on reasonably large, high dimensional data sets. (Received August 08, 2013)

1096-52-494 **Susanna Dann*** (danns@missouri.edu). *The Lower Dimensional Busemann-Petty Problem in the Complex Hyperbolic Space.*

The lower dimensional Busemann-Petty problem asks whether origin-symmetric convex bodies in $\mathbb{R}^n$ with smaller volume of all k-dimensional sections necessarily have smaller volume. The answer is negative for $k > 3$. The problem is still open for $k = 2, 3$. We study this problem in the complex hyperbolic n-space and prove that the answer is affirmative only for sections of complex dimension one and negative for sections of higher dimensions. (Received September 04, 2013)

1096-52-1493 **Yumi Li*** (yumi.li92@gmail.com), **Jordan Awan**, **Claire Frechette** and **Liz McMahon**. *Finite Geometry in the Card Game SET.*

The card game SET serves as an excellent model for the finite geometry AG(4,3). Using that model, previous researchers have found partitions of AG(4,3) into 4 disjoint maximal caps along with a distinguished point/card. We define a new geometric object, a demicap - a maximal cap can be written as the union of two disjoint demicaps. We will present results about these demicaps, which provide insight into the maximal cap partitions of AG(4,3). (Received September 15, 2013)

1096-52-1533 **Jeremiah D Bartz*** (jbartz@fmarion.edu). *Multinets in $\mathbb{P}^2$ and $\mathbb{P}^3$.* Preliminary report.

Multinets are specific configurations of points and lines in $\mathbb{P}^2$ which play an important role in the study of resonance varieties of the complement of a complex hyperplane arrangement. Very few examples are known. In this talk, a method for producing multinets from a net in $\mathbb{P}^3$ is presented. Implementing this method, numerous new and interesting examples are identified. These examples provide additional evidence supporting the conjecture of Pereira and Yuzvinsky that all multinets are degenerations of nets. (Received September 16, 2013)

1096-52-1726 **Marcus Bishop*** (marcus.bishop@wne.edu). *Computations for Coxeter arrangements and Solomon's descent algebra.* Preliminary report.
In joint work with J. M. Douglass, G. Pfeiffer, and G. Röhrle we refine a conjecture of Lehrer and Solomon on the structure of the Orlik-Solomon algebra of a finite Coxeter group W and we relate it to the descent algebra of W. As a result, we claim that both the group algebra of W and the Orlik-Solomon algebra of W can be decomposed into sums of induced one-dimensional representations of element centralizers, one for each conjugacy class of elements of W. To date the conjecture has been verified for the symmetric groups and the dihedral groups, as well for all Coxeter groups of exceptional type other than the group of type E_8. We discuss the proof in the case of the symmetric and dihedral groups and time permitting, the computer implementation for the exceptional groups. (Received September 16, 2013)

1096-52-2281 **Ye Luo*** (luoye@math.gatech.edu), 686 Cherry St, School of Math, Georgia Institute of Technology, Atlanta, GA 30332. *Linear systems of tropical curves: a geometric perspective.*
A linear systems of a tropical curve are defined to be a subset of a linear equivalent class of divisors on the tropical curve.

Interestingly there are some unconventional geometric properties of these linear systems. I am going to talk about related geometric notions: tropical convexity, geodesics, dimensions, local fan structures and global cell complex structures. I will also give a definition of a new rank function to the linear systems.

As an application, there is a related talk (presented by Madhusudan Manjunath) in this session on "Smoothing of limit g_d^1 on metrized complexes". (Received September 17, 2013)

1096-52-2783 **Yusu Wang*** (mkl@ams.org). *Computing geometric and topological summaries.*
Algorithms for computing geometric and topological summaries of data including persistence homologies, computational aspects of manifold learning, and distance based computations in high dimensions. (Received October 15, 2013)

1096-52-2785 **Matthew Kahle*** (mkl@ams.org). *Random geometry and topology.*
The geometry and topology induced by random processes, the topology of random clique complexes, random geometric complexes, limit theorems of Betti numbers of random simplicial complexes. (Received October 15, 2013)

53 ► Differential geometry

1096-53-135 **Peter Spaeth*** (spaeth@psu.edu), Peter Spaeth, Mathematics and Natural Sciences, 3000 Ivyside Park, Altoona, PA 16601. *The helicity invariant and topological strictly contact dynamics.*
If X is a divergence-free vector field on a closed 3-manifold M equipped with a volume form μ, then the 2-form $\iota_X\mu$ is closed. Assuming it is exact, one may choose a primitive 1-form β_X and define the helicity of X to be the real number

$$\mathrm{Helicity}(X) = \int_M \beta_X \wedge d\beta_X.$$

In a joint project with S. Müller, we compute the helicity of a vector field X that preserves a regular contact form α on M in terms of the basic contact Hamiltonian H that generates X. This provides a simple criterion for a loop of α-preserving diffeomorphisms to be non-contractible.

Combined with results from C^0-symplectic and contact topology this computation also allows us to extend the helicity to certain measure preserving isotopies of *homeomorphisms* of M. (Received August 07, 2013)

1096-53-157 **Paul Gallagher** (paul.robert.gallagher@gmail.com), **David Hu*** (dh363@georgetown.edu), **Zane Martin** (zan3rm@gmail.com), **Maggie Miller** (mhmiller@math.utexas.edu) and **Byron Perpetua** (bjp1@williams.edu). *The Isoperimetric Problem in the Plane with Density $e^{-1/r}$.* Preliminary report.
We study the isoperimetric problem in the plane with weighting or density $e^{-1/r}$. The isoperimetric problem seeks to enclose prescribed weighted area with minimum weighted perimeter. For unit density (the Euclidean case), the answer is of course any circle. For density $e^{-1/r}$, isoperimetric curves are conjectured to pass through the origin. (Received August 10, 2013)

1096-53-251 **Barry Minemyer*** (minemyer@alfred.edu), 1 S Brooklyn Ave, Apt C7, Wellsville, NY 14895. *Simplicial Isometric Embeddings of Indefinite Metric Polyhedra.*

In 1954-1956 John Nash proved that every Riemannian manifold admits an isometric embedding into Euclidean space. His results were extended to manifolds endowed with an indefinite metric tensor by Greene and Gromov/Rokhlin independently in 1970. More specifically, they proved that such manifolds admit isometric embeddings into Minkowski space of an appropriate signature. In this talk we will discuss combinatorial analogues of both of these results to polyhedra whose simplices are endowed with a metric tensor of arbitrary signature. (Received August 23, 2013)

1096-53-309 **Michael William Berglund*** (berglund@math.uga.edu), University of Georgia, Department of Mathematics, Athens, GA 30602. *Bounding total curvature of random planar polygons sampled under the symmetric measure.*

By utilizing results known for random matrices, we are able to quantify the intuitive notion that small segments of random polygon forget the closure condition. We can then apply this result to produce bounds on the expectations of various quantities, such as total curvature and self-intersection. (Received August 27, 2013)

1096-53-449 **Ye-Kai Wang*** (yw2293@math.columbia.edu). *Minkowski identities for codimension-2 surfaces and an Alexandrov-type theorem.*

We prove two Minkowski identities for spacelike 2-surfaces in Minkowski spacetime or, more generally, spacetimes equipped with a conformal Yano-Killing tensor. The identities recover the classical Minkowski identities when the surface lies in a totally geodesic slice. As an application, we prove an Alexandrov-type theorem for 2-surface in the spherically symmetric spacetimes. If a surface has constant null expansion and zero torsion with respect to a null normal vector, then the surface, under a regularity assumption, lies in the shear-free light cone. This is a joint work with Mu-Tao Wang. (Received September 03, 2013)

1096-53-502 **Jeffrey Danciger** (jdanciger@math.utexas.edu), **Sara Maloni*** (sara_maloni@brown.edu) and **Jean-Marc Schlenker** (jean-marc.schlenker@uni.lu). *Ideal polyhedra in anti-de Sitter space.* Preliminary report.

In this talk we will consider ideal polyhedra in 3–dimensional anti-de Sitter space $\mathbb{AdS}^3$. After a brief introduction to $\mathbb{AdS}$–geometry, we will show that any hyperbolic metric on the sphere with n cusps, and a distinguished "equator", can be uniquely realized as the induced metric on a convex ideal polyhedron in the anti-de Sitter space $\mathbb{AdS}^3$. Moreover we will characterize the possible dihedral angles of those ideal polyhedra in $\mathbb{AdS}^3$, and show that each ideal polyhedron is characterized by its angles. (This is a joint work with J. Danciger and J-M Schlenker.) (Received September 05, 2013)

1096-53-585 **Sergii M Kutsak*** (sergiikutsak@ufl.edu). *Invariant contact structures on 7-dimensional nilmanifolds.*

We give the list of all 7-dimensional nilpotent real Lie algebras that admit a contact structure. Based on this list, we describe all 7-dimensional nilmanifolds that admit an invariant contact structure. (Received September 06, 2013)

1096-53-637 **Jacob Bernstein*** (bernstein@math.jhu.edu), 3400 N Charles St, Department of Mathematics, Krieger Hall 408, Baltimore, MD 21218, and **Giuseppe Tinaglia**. *Topological type of Limit Laminations of Embedded Minimal Disks.*

We consider two natural classes of minimal laminations in three-manifolds. Both classes may be thought of as limits – in different senses – of embedded minimal disks. In both cases, we prove that, under a natural geometric assumption on the three manifold, the leaves of these laminations are topologically either disks, annuli or Möbius bands. This answers a question posed by Hoffman and White. (Received September 08, 2013)

1096-53-655 **Yueh-Ju Lin*** (ylin4@nd.edu), Hurley 255, Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556. *Connected sum construction of constant Q-curvature manifolds in higher dimensions.*

For a compact Riemannian manifold (M^n, g) of dimension $n \geq 6$ with constant Q-curvature and satisfying a nondegeneracy condition, we show that one can construct many examples of constant Q-curvature manifolds by a gluing construction. In particular, we prove the existence of solutions of a fourth-order partial differential equation, which implies the existence of a smooth metric with constant Q-curvature on the connected sum. In this talk, I will begin with definitions of Q-curvature and Paneitz operator, and then give an overview of the gluing procedure. (Received September 09, 2013)

1096-53-668 **Matthew McGonagle*** (mcgonagle@math.jhu.edu), Department of Mathematics, Johns Hopkins University, Baltimore, MD 21218, and **John Ross**. *The Hyperplane is the Only Stable, Smooth Solution to the Isoperimetric Problem in Gaussian Space.*

We study hypersurfaces $\Sigma^n \subset \mathbb{R}^{n+1}$ that are second order stable critical points for minimizing $\int_\Sigma e^{-\frac{|x|^2}{4}}\,dA$ for compact variations that preserve gaussian weighted volume. These Σ satisfy the curvature condition $H = \langle x, N\rangle/2 + C$ where C is a constant.

Our first main result is that for non-planar Σ, bounds for the index of the associated Jacobi operator L, acting on volume preserving variations, gives us that Σ splits off a linear space. A corollary of this result is that hyperplanes are the only stable smooth complete solutions to this gaussian isoperimetric type problem, and that there are no hypersurfaces of index one. Finally, we show that for the case of $\Sigma^2 \subset \mathbb{R}^3$, there is a gradient decay estimate for fixed bound $|C| \leq M$ (where C is from the curvature condition) and Σ obeying an appropriate volume growth bound. This shows that with good volume growth bounds and uniform bounds on $|C|$, in the limit as $R \to \infty$, stable $(\Sigma, \partial\Sigma) \subset (B_{2R}(0), \partial B_{2R}(0))$ approach hyperplanes. (Received September 09, 2013)

1096-53-675 **Jesse Ratzkin*** (jesse.ratzkin@uct.ac.za), Department of Maths and Applied Maths, University of Cape Town, Private Bag X1, Rondebosch, Cape Town, W. Cape 7701, South Africa. *Conformally flat, constant Q-curvature metrics with isolated singularities.* Preliminary report.

For $n \geq 5$ let $\Omega \subset \mathbf{R}^n$ be a domain with smooth boundary, and let $u \in \mathcal{C}^\infty(\Omega)$ with $u > 0$. Then the conformally flat metric $g_{ij} = u^{\frac{4}{n-4}}\delta_{ij}$ has (fourth-order) Q-curvature given by

$$Q_g = \frac{4}{n-2} u^{-\frac{n+4}{n-4}} \Delta^2 u,$$

where Δ is the usual Laplace operator. The Q-curvature is an interesting quantity in conformal and Riemannian geometry, and it in some way generalizes scalar curvature. Also, the PDE one obtains by setting Q_g to a positive constant is exactly the Euler-Lagrange equation to find the best constant in the Sobolev embedding $W^{2,2}(\Omega) \hookrightarrow L^{\frac{2n}{n-4}}$. Notice that the exponent $p = \frac{2n}{n-4}$ is exactly the exponent where the Sobolev embedding loses compactness, and so one should expect "bubbling" in the sense originally described by Uhlenbeck, leading to singular solutions.

I will discuss solutions to the PDE

$$\Delta^2 u = \frac{n(n-4)(n^2-4)}{16} u^{\frac{n+4}{n-4}}, \quad u > 0 \text{ in } \mathbf{B}\backslash\{0\},$$

which give conformally flat metrics with constant positive Q-curvature in a punctured ball. In particular, I will describe some of the asymptotic behavior of $u(x)$ as $|x| \to 0$. (Received September 09, 2013)

1096-53-680 **Joanna Nelson*** (nelson@math.ias.edu). *Cylindrical contact homology as a well-defined homology?*

In this talk I will then explain how the heuristic arguments sketched in literature since 1999 fail to define a homology theory. These issues will be made clear with concrete examples and we will explore what stronger conditions are necessary on the growth rates of the indices of Reeb orbits. These conditions will enable us to provide a foundation for a well-defined cylindrical contact homology in dimension 3, which does not depend on polyfold machinery. In addition a new approach will be given that allows us to compute cylindrical contact for a large class of examples which admit contact forms that are admissible under the stronger conditions required. This approach is applicable to prequantization spaces and the links of simple singularities. (Received September 09, 2013)

1096-53-721 **Chenxu He*** (che@math.ou.edu), Department of Mathematics, University of Oklahoma, Norman, OK 73019, and **Huai-Dong Cao**. *Linear stability of gradient shrinking Ricci solitons.*

Shrinking Ricci solitons are self-similar solutions to Hamilton's Ricci flow and natural extensions of Einstein metrics of positive scalar curvature. They are also critical points of a certain functional defined by Perelman. In this talk we will discuss geometry of Ricci solitons, in particular the second variation of Perelman's shrinker entropy and stability question. We will present the full classification of the linear stability of Perelman's entropy on symmetric spaces of compact type. (Received September 09, 2013)

1096-53-734 **Mario Micheli*** (mariomicheli@gmail.com), University of Washington, Department of Mathematics, C-434 Padelford Hall, Box 354350, Seattle, WA 98195. *A class of Riemannian metrics for shape deformation analysis.*

In recent years the rapid development of precise acquisition techniques for medical data has prompted applied mathematical work on the quantification of geometric deformation, for the ultimate purpose of performing statistics (e.g. template estimation, classification, regression analysis, and so on) on "shape spaces"; examples of shapes are curves in two or three dimensions, surfaces, images, tensor fields, or sets of feature points. In particular, the action of groups of diffeomorphisms induces Riemannian metrics on shape spaces; such approach is known as Large Deformation Diffeomorphic Metric Mapping (LDDMM). One may choose different metrics (inner products of vector fields) on the tangent space of the diffeomorphisms group, and these will induce different metrics and geometries on the shape spaces. In this talk we shall characterize the class of translation- and rotation-invariant metrics on group of diffeomorphisms, and provide examples of metrics whose geodesics in the group are generated by curl-free or divergence-free vector fields. The latter may prove especially useful in medical applications where deformations are known to preserve volume (for example, for deformations of the tissues of the heart). (Received September 09, 2013)

1096-53-744 **Yakov Eliashberg*** (eliash@math.stanford.edu), Department of Mathematics, Stanford University, Stanford, CA 94305. *Recent Advances in Symplectic Flexibility.*

From the first steps of symplectic topology in 1980s flexible and rigid methods were coexisting and competing. While rigid methods dominated the development, the progress on the flexible side which was achieved in the last 3 years in the work of E. Murphy, K. Cieliebak, T. Ekholm, I. Smith and the author established some limits on how far symplectic rigidity results could be extended. In particular, we will discuss new flexibility phenomena in Lagrangian intersection theory and their implications. (Received September 09, 2013)

1096-53-753 **Grigori Avramidi**, **Tam Nguyen Phan** and **Yunhui Wu*** (yw22@rice.edu), Department of Mathematics, Rice University, 6100 Main Street, Houston, TX 77005. *Geometry and topology of noncompact, complete, finite volume, Riemannian 4-manifolds M with sectional curvature $-1 < K < 0$.*

We study noncompact, complete, finite volume, Riemannian 4-manifolds M with sectional curvature $-1 < K < 0$. We prove that $\pi_1 M$ cannot be a 3-manifold group. A classical theorem of Gromov says that M is homeomorphic to the interior of a compact manifold $\overline{M}$ with boundary $\partial\overline{M}$. We show that for each π_1-injective boundary component C of $\overline{M}$, the map i_* induced by inclusion $i\colon C \to \overline{M}$ has infinite index image $i_*(\pi_1 C)$ in $\pi_1\overline{M}$. We also prove that M cannot be homotoped to be contained in $\partial\overline{M}$. If time permitted, we will also discuss the topology for ends of $\partial\overline{M}$. The works are joint with Grigori Avramidi and Tam. N. Phan. (Received September 09, 2013)

1096-53-858 **Brett Kotschwar** (kotschwar@asu.edu), P.O. Box 871804, Tempe, AZ 85287, and **Lu Wang*** (lwang@math.jhu.edu), 3400 N. Charles Street, Baltimore, MD 21218. *On the Rigidity of Ricci Solitons.*

In this talk, we will discuss some recent progress on the rigidity at infinity of Ricci solitons using Carleman type technique. This is joint with Brett Kotschwar at Arizona State University. (Received September 10, 2013)

1096-53-864 **Michael Munn*** (munnm@missouri.edu), 210 Math. Sciences Building, Dept. of Mathematics, University of Missouri, Columbi, MO 65201, and **Sajjad Lakzian**. *Metric Perspectives of the Ricci Flow.*

We consider compact, Riemannian manifolds M_1, M_2 each equipped with a family of metrics $g_1(t), g_2(t)$ (resp.) evolving by the Ricci flow. We introduce the notion of a super Ricci flow for a family of distance metrics defined on the union $M_1 \sqcup M_2$ and show that this property holds when the distance function between points in M_1 and M_2 evolves by the heat equation. We also discuss possible applications and examples. This is joint work with Sajjad Lakzian. (Received September 10, 2013)

1096-53-1112 **Michael B. Deutsch*** (mdeutsch@impa.br), IMPA, Estrada Dona Castorina 110, Rio de Janeiro, RJ 22460-320, Brazil. *Scharzian derivatives and Euclidean-minimal surfaces.* Preliminary report.

The classical Schwarzian derivative of a meromorphic function has been generalized in many contexts and from a variety of points of view. An impressive example due to Osgood and Stowe is a Schwarzian concept for conformal maps between Riemannian manifolds, a tensor inspired by a similar derivative for a harmonic map, obtained by considering the conformal factor of an associated minimal surface in Euclidean 3-space. In this talk we consider an altogether different and somewhat narrower generalization, obtained by reasoning in just the opposite direction: Starting with a harmonic map (a minimal surface) in Euclidean n-space, we will associate a Schwarzian derivative by considering the complex conformal geometry of the Gauss lift. The result can be interpreted as a geometric invariant which, together with a generalized Hopf tensor, determines a minimal surface up to a certain non-isometric transform which we explicitly describe. (Received September 13, 2013)

1096-53-1202 **Selman Akbulut** (akbulut@math.msu.edu) and **Mustafa Kalafat*** (mkalafat@tunceli.edu.tr). *Algebraic topology of G_2 manifolds.*

We discuss various results about the topology of oriented Grassmannian bundles related to the exceptional Lie group G_2. From these results we deduce existence of certain special 3 and 4 dimensional submanifolds of G_2 manifolds with special properties, which were previously used with S. Salur to study Mirror duality phenomena in G_2 manifolds. (Received September 13, 2013)

1096-53-1267 **Caner Koca*** (caner.koca@vanderbilt.edu), Vanderbilt University, Department of Mathematics, 1326 Stevenson Center, Nashville, TN 37240. *Bach-Maxwell Equations and Extremal Kähler Metrics.*

On a compact oriented 4-manifold one can introduce an interesting coupled system of PDEs, called the Bach-Maxwell equations, for the Riemannian metrics and harmonic 2-forms. These equations can be thought as the conformal versions of the classical Einstein-Maxwell Equations in physics, and therefore the solutions are geometrically significant. In this talk, I will show that extremal Kahler metrics on compact complex surfaces are solutions of these equations for a suitable 2-form. In particular, Kähler-Einstein metrics or more generally, Kähler metrics of constant scalar curvature are among the solutions. I will also discuss various variational characterizations of the solutions of Bach-Maxwell Equation, and possible applications in study of extremal Kähler metrics. (Received September 14, 2013)

1096-53-1379 **Charles P Boyer*** (cboyer@math.unm.edu). *Sasaki join, transverse Hamiltonian 2-forms, and Sasaki-Einstein metrics.* Preliminary report.

My talk is based on joint work with Christina Tønnesen-Friedman. We apply a general geometrical approach using the Sasaki join construction for quasi-regular contact structures together with transverse Hamiltonian 2-forms to recover Sasaki-Einstein metrics discovered by physicists. Our geometrical approach allows us to give an algorithm for computing the cohomology ring of the Sasaki-Einstein manifolds. We also give formulae describing the homotopy, homeomorphism, and diffeomorphism types. (Received September 15, 2013)

1096-53-1383 **James N. Damon** and **Ellen K. Gasparovic*** (ellen@math.duke.edu). *Positional geometry of multi-object configurations from skeletal linking structures.*

We introduce “medial/skeletal linking structures” for configurations of multiple objects, which build upon the individual skeletal structures of the objects in a minimal way, and which enable us to analyze the “positional geometry” of the configuration along with the shapes of the individual objects. We use the skeletal linking structure to introduce and compute volumetric invariants of the positional geometry of the collection, which include measures of relative closeness and relative significance of the individual objects. The invariants are computed via “skeletal linking integrals” computed directly on the skeletal sets, and we use them to construct a “tiered linking graph.” When given thresholds of closeness and significance are applied to this graph, they yield subgraph(s) identifying subconfigurations and provide a hierarchical ordering of the objects. (Received September 15, 2013)

1096-53-1527 **Christopher L. Rogers*** (crogers@uni-math.gwdg.de), Mathematisches Institut, Georg-August-Universität Göttingen, D-37073 Göttingen, Germany. *Symmetries of closed differential forms and Lie algebras up to homotopy.*

In this talk, I will consider higher degree closed differential forms as generalizations of symplectic structures. Canonically associated to any manifold equipped with such a closed form is an algebraic structure called an L_∞-algebra, or Lie algebra up to homotopy. This structure is built from multilinear bracket-like operations on so-called “Hamiltonian forms”, and thus plays the role of the Poisson algebra in this context. I'll explain how to use this algebraic structure to construct moment maps for group actions on such manifolds, and also describe a generalization of Kirillov-Kostant-Souriau geometric prequantization. Along the way, I will present several interesting examples, and highlight relationships between this work and other approaches used in generalized geometry and bundle gerbe theory. Many of these results are due to recent joint work (arXiv:1304.2051)with Y. Frégier (MIT/Zurich) and M. Zambon (ICMAT/Madrid). (Received September 16, 2013)

1096-53-1545 **Ibrahim Unal*** (uibrahim@metu.edu.tr), Middle East Technical University, Northern Cyprus Campus, Kalkanli, Mersin 10 Guzelyurt, Turkey. *ϕ-free Submanifolds and Convexity in Calibrated Manifolds.*

F. R. Harvey and H. B. Lawson, Jr. canonically generalized the classical plurisubharmonic functions and convexity in complex geometry to all calibrated manifolds, and called them ϕ-plurisubharmonic functions and ϕ-convexity on a calibrated manifold (X, ϕ). One of the techniques to construct enormous families of strictly

ϕ-convex domains with different topological types is using ϕ-free submanifolds, analogues of totally real submanifolds. In this talk, I will speak about the topology of ϕ-free submanifolds for well-known calibrations in Quaternion-Kähler, G_2 and $Spin(7)$ manifolds and explain some recent results about ϕ-free embeddings, which use h-principle. (Received September 16, 2013)

1096-53-1740 **J Davidov**, **G Grantcharov*** (grantchg@fiu.edu), **O Mushkarov** and **M Yotov**.
Compact complex surfaces with geometric structures related to split quaternions.

We study the question of existence of geometric structures on compact complex surfaces that are related to split quaternions. These structures, called para-hypercomplex para-hyperhermitian and para-hyperkähler, are analogs of the hypercomplex hyperhermitian and hyperkähler structures in the definite case. Every compact complex surface admitting a para-hyperhermitian structure has vanishing first Chern class and we show that, unlike the definite case, many of these surfaces carry infinite dimensional families of such structures. We discuss also the existence of locally conformal para-hyperkähler structures. (Received September 16, 2013)

1096-53-1797 **Rebecca E Glover*** (rglover3@z.rochester.edu), Department of Mathematics, University of Rochester, Rochester, NY 14627. *Generalized complex geometry of hyperkähler and Quaternionic Kähler manifolds.*

Generalized complex geometry is a simultaneous generalization of symplectic and complex geometry. In this talk, we will discuss generalized complex structures on hyperkähler, quaternionic Kähler and hypercomplex manifolds. We will define and explain properties of a generalized twistor space for these structures: a $\mathbb{C}P^1 \times \mathbb{C}P^1$-bundle of generalized complex structures defined on the underlying manifold. (Received September 16, 2013)

1096-53-1822 **Anton Lukyanenko*** (lukyane2@illinois.edu), Department of Mathematics, 1409 W. Green Street, Urbana, IL 61801. *Uniformly quasi-regular mappings on sub-Riemannian manifolds.*

The study of quasi-conformal mappings on sub-Riemannian (sR) manifolds, such as the Heisenberg group, is closely linked to the study of complex hyperbolic geometry. Quasi-regularity is a generalization of quasi-conformality that allows for branching. A mapping is uniformly quasi-regular if all of its iterates have bounded dilatation.

We show that: (1) sR lens spaces admit UQR mappings with non-empty branch set, and (2) every UQR mapping admits an invariant measurable conformal structure.

This is joint work with K. Fässler and K. Peltonen. (Received September 16, 2013)

1096-53-1861 **Mihai Bailesteanu*** (mbailest@z.rochester.edu), 801 Hylan Building, Department of Mathematics, University or Rochester, Rochester, NY 14627. *A reduction theorem for Spin(7) structures.* Preliminary report.

Spin(7) manifolds are 8 dimensional Riemannian manifolds that have a cross product on their tangent bundles, which generate a 4-form. We can define some canonical vector fi elds on these manifolds, which in turn allows us to defi ne a type of moment map. We will discuss some recent developments. (Received September 16, 2013)

1096-53-1899 **Claude LeBrun***, Department of Mathematics, SUNY, Z-3651, Stony Brook, NY 11794.
Einstein Metrics, Curvature Functionals, and Conformally Kähler Geometry.

It is well known that Einstein metrics on smooth compact manifolds are necessarily critical points of certain natural curvature functionals. In most dimensions, however, one can show by example that Einstein metrics of special holonomy are not usually minima of even the best-behaved such curvature functionals. In dimension 4, however, the situation is dramatically different. We will see that conformally Kähler, Einstein metrics on compact 4-manifolds do indeed minimize an appropriate curvature functional. However, the curvature functional one ought to consider turns out to crucially depend on the sign of the Einstein constant! (Received September 16, 2013)

1096-53-1942 **Maree Jaramillo*** (maree@math.ucsb.edu), Department of Mathematics, University of California, Santa Barbara, CA 93106. *Fundamental Groups of Spaces with Bakry-Emery Ricci Tensor Bounded Below.*

The Bakry-Emery Ricci tensor is a natural extension of Ricci curvature on smooth metric measure spaces. Since topological and geometric information can be obtained for manifolds with Ricci curvature bounded from below, it is natural to ask if the same information holds true for smooth metric measure spaces with Bakry-Emery Ricci tensor bounded from below. Using Guofang Wei and Will Wylie's comparison theorems and an extension of Kevin Brighton's gradient estimate on smooth metric measure spaces, we extend the Almost Splitting Theorem of Cheeger-Colding to the smooth metric space setting. Using this Almost Splitting theorem, we show that the fundamental group of the smooth metric measure space with a lower bound on volume has almost abelian fundamental group. We also show that the number of generators of the fundamental group of a smooth metric measure space with Bakry-Emery Ricci tensor bounded from below is uniformly bounded. The results on the fundamental group are extensions of theorems which hold for Riemannian manifolds with Ricci curvature bounded from below. (Received September 16, 2013)

1096-53-1965 **Lizhi Chen*** (lchen@math.okstate.edu), Department of Mathematics, Oklahoma State University, Mathematical Sciences 401, Stillwater, OK 74078. $\mathbb{Z}_2-$*Systolic* $(1,2)-$*Freedom of* $\mathbb{R}P^3\#\mathbb{R}P^3$.

We show that the $3-$manifold $\mathbb{R}P^3\#\mathbb{R}P^3$ has $\mathbb{Z}_2$ coefficient $(1,2)$ homologically systolic freedom. In other words, we can construct Riemannian metrics on $\mathbb{R}P^3\#\mathbb{R}P^3$ of arbitrarily small volume, such that length$(\gamma)\cdot$area$(\Sigma) \geqslant 1$, for every geodesic loop γ which is nontrivial in $H_1(\mathbb{R}P^3\#\mathbb{R}P^3;\mathbb{Z}_2)$ and every embedded smooth surface which is nontrivial in $H_2(\mathbb{R}P^3\#\mathbb{R}P^3;\mathbb{Z}_2)$. Previously M. Freedman has proved that the $3-$manifold $S^2\times S^1$ exhibits $(1,2)$ systolic freedom over $\mathbb{Z}_2$, which is the first example of systolic freedom over torsion coefficients. The $\mathbb{Z}_2$ systolic freedom of $\mathbb{R}P^3\#\mathbb{R}P^3$ is another systolic freedom example over torsion coefficients of $3-$manifolds after Freedman's example.In this work, Freedman's technique is used to construct metrics on $\mathbb{R}P^3\#\mathbb{R}P^3$. The $3-$manifold $\mathbb{R}P^3\#\mathbb{R}P^3$ is doubly covered by the surface bundle $S^2\times S^1$, so the arithmetic hyperbolic surface construction and the Dehn surgery technique can be employed. (Received September 16, 2013)

1096-53-2102 **Tara S Holm*** (tara.holm@cornell.edu), Department of Mathematics, Malott Hall, Ithaca, NY 14853-4201, and **Ana Rita Pires**. *The topology of toric origami manifolds.*

A folded symplectic form on a manifold is a closed 2-form with the mildest possible degeneracy along a hypersurface. A special class of folded symplectic manifolds are the origami manifolds. In the classical case, toric symplectic manifolds can classified by their moment polytope, and their topology (equivariant cohomology) can be read directly from the polytope. In this talk we examine the toric origami case: we will recall how toric origami manifolds can also be classified by their combinatorial moment data, and present some theorems, almost-theorems, and conjectures about the topology of toric origami manifolds. (Received September 17, 2013)

1096-53-2136 **Craig J. Sutton*** (craig.j.sutton@dartmouth.edu), Dartmouth College, Hanover, NH 03755. *On the Poisson relation for compact symmetric spaces.* Preliminary report.

Motivated in part by considerations from quantum mechanics, it is a long-standing folk-conjecture that the spectrum of a manifold (i.e., the sequence of eigenvalues of the associated Laplace operator) determines its length spectrum (i.e., the set consisting of the lengths of closed orbits of the associated geodesic flow). This conjecture is known to be true for generic (i.e., sufficiently "bumpy") manifolds; however, our understanding in the homogeneous setting—where closed geodesics come in large families—is rather incomplete. In this talk we will use wave trace techniques to explore the validity of this conjecture in the case of compact irreducible symmetric spaces, which serve as a large and natural class of standard model spaces in geometry. In particular, we will confirm the conjecture for classical Lie groups equipped with a bi-invariant metric by showing that the Poisson relation is an equality. That is, we will use the trace formula of Duistermaat and Guillemin to show that for such manifolds the singular support of the trace of the associated wave group is equal to the length spectrum. (Received September 17, 2013)

1096-53-2195 **Dusa McDuff*** (dusa@math.columbia.edu), Mathematics MC4410, Columbia University, 2990 Broadway, New York, NY 10027. *Symplectic Topology Today: Recent results and open questions.*

This lecture will first introduce the basic notions of symplectic/contact geometry and explain some foundational results (such as the non-squeezing theorem). It will then describe some motivating questions (the flexibility/rigidity dichotomy, the Arnold and Weinstein conjectures, the existence/uniqueness problem), and some recent progress in answering them. (Received September 17, 2013)

1096-53-2197 **Dusa McDuff*** (dusa@math.columbia.edu), Mathematics MC4410, Columbia University, 2990 Broadway, New York, NY 10027. *Symplectic Topology Today: Embedding questions: obstructions and constructions.*

This will discuss questions of symplectic embeddings, describing some different constructions of embeddings (notably by Guth and Buse–Hind) and some obstructions to their existence (specially recent work of Hutchings, Hind, Kerman, and Lisi). (Received September 17, 2013)

1096-53-2198 **Dusa McDuff*** (dusa@math.columbia.edu), Mathematics MC4410, Columbia University, 2990 Broadway, New York, NY 10027. *Symplectic Topology Today: Embedding ellipsoids and Fibonacci numbers.*

This will concentrate on the question of when one four dimensional ellipsoid embeds symplectically into another, a problem that has the virtue of having a complete answer. The solution when the target is a ball gives rise to an interesting capacity function worked out by McDuff–Schlenk, whose definition involves continued fractions and the Fibonacci numbers. The relevant combinatorics have other interesting applications, notably to the calculation of the number of integer points in rational affine triangles. (Received September 17, 2013)

1096-53-2261 **Faen Wu*** (fewu@bjtu.edu.cn), Department of Mathematics, Polytechnic Institute of NYU, New York, NY, and **Yueshan Xiong** and **Xinnuan zhao**. *Classification of Quadratic Harmonic Maps of S7 into S7.*

A complete classification of full quadratic harmonic maps of 7-sphere S7 into itself is obtained. It is shown that any full quadratic harmonic map of 7-sphere S7 into itself is equivalent to either the gradient map of the cubic isoparametric polynomial of Cartan or a map depending only on one parameter. The components of the map in latter case are explicitly given. (Received September 17, 2013)

1096-53-2275 **Jordan A. Watts*** (jawatts@illinois.edu), Department of Mathematics, 1409 W. Green Street, Urbana, IL 61801. *Basic Differential Forms on Geometric Stacks.*

We will show that the complex of basic differential forms of a geometric stack represented by a proper Lie groupoid are isomorphic to the complex of differential forms on its diffeological coarse moduli space. (Received September 17, 2013)

1096-53-2423 **T. H. Wears*** (wearsth@longwood.edu) and **Joseph Gills** (joseph.gills@live.longwood.edu). *The Geometry of Curves and Surfaces in the Heisenberg Group.* Preliminary report.

We study the geometry of curves and surfaces in the three-dimensional Heisenberg group equipped with left invariant metric (Riemannian or Lorentzian) by utilizing the Fels-Olver moving frame method. In doing so, we present complete sets of differential invariants for curves and surfaces in the Heisenberg group when the dimension of the isometry group is four. In addition, we provide a geometric interpretation of the invariants for certain classes of curves and surfaces and provide a brief comparison with differential invariants of curves and surfaces generated by more traditional geometric methods. (Received September 17, 2013)

1096-53-2597 **Yu-Wen Hsu*** (yu-wen.hsu@yale.edu), Mathematics Department, Yale University, 10 Hillhouse Avenue, New Haven, CT 06511. *Curve shortening flow and smooth projective planes.*

In this talk, we present a paper in which we use curve shortening flow to solve a problem in geometric topology. We show that any two-dimensional smooth projective plane can be smoothly deformed through a family of smooth projective planes into one which is isomorphic to RP^2. In addition, we prove that any two smooth embedded curves on RP^2 which intersect transversally at exactly one point, converge to two different geodesics under the flow. (Received September 17, 2013)

1096-53-2710 **Rakesh Kumar*** (dr_rk37c@yahoo.co.in), Rakesh Kumar, Department of Applied Sciences, Faculty of Engineering, Punjabi University, Patiala, Punjab 147002, India. *Every totally umbilical GCR-lightlike submanifold of an indefinite nearly Kaehler manifold is totally geodesic.*

Due to the significant applications of CR structures in relativity and growing importance of lightlike submanifolds in mathematical physics and relativity, the notion of CR-lightlike submanifolds of indefinite Kaehler manifolds were introduced, which have direct relation with physically important asymptotically flat space time which further lead to Twistor theory of Penrose and Heaven theory of Newman. But CR-lightlike submanifolds do not include complex and totally real lightlike submanifolds. Therefore SCR-lightlike submanifolds of indefinite Kaehler manifolds were introduced which contain complex and totally real subcases but there was no inclusion relation between CR and SCR cases. Thus further GCR-lightlike submanifolds of indefinite Kaehler manifolds were introduced. In present paper, we prove that there do not exist totally umbilical GCR-lightlike submanifolds of indefinite nearly Kaehler manifolds other than totally geodesic GCR-lightlike submanifolds. (Received September 18, 2013)

54 ► General topology

1096-54-184 **Sukhdev Singh*** (sukhdev.15829@lpu.co.in), Department of Mathematics, Lovely Professional University, Jalandhar-Delhi G.T. Road, (NH-1), Phagwara, 144411, India, and **Rajiv K. Srivastava** (rajiv.maths.ibs@gmail.com), Department of Mathematics, Institute of Basic Science, Khandari, Dr. B. R. Ambedkar University, Agra, 282002, India.
Certain Order Topologies on the Bicomplex Space and a Study of Bicomplex Nets.

In this paper, we have studied the topological properties of the bicomplex space C_2. We have defined three order topologies and a metric topology on C_2. We have compared the order topologies with each other and also with the metric topology.

We have initiated the study of nets in C_2. Different types of confinements of bicomplex nets have been characterized in terms of convergence of the component nets. We have also initiated the study of clustering of bicomplex nets. Clustering on different types of zones in C_2 have been defined. We have investigated the confinements and clustering of the bicomplex nets in different order topologies. Finally, investigations have been made connecting clustering of a bicomplex net and confinement of its subnets. (Received August 16, 2013)

1096-54-507 **Bernd Losert** (berndlosert@gmail.com), 4000 Central Florida Blvd., Orlando, FL 32816, and **Gary Richardson*** (gary.richardson@ucf.edu), 4000 Central Florida Blvd., Orlando, FL 32816. *Cauchy Continuous Actions.*

A Cauchy monoid acting continuously on a Cauchy space is investigated. A completion theory is studied in this context. Cauchy continuous extension of the action to the completion of the underlying Cauchy space is the primary focus here. Completions of generalized quotient spaces are also considered. It is shown that the completion of the generalized quotient space coincides with the generalized quotient of the completion of the underlying Cauchy space. (Received September 05, 2013)

1096-54-510 **Hatim Boustique*** (hboustique@valenciacollege.edu), 701 N Econlockhatchee Trail, Orlando, FL 32825, **Bernd Losert** (berndlosert@gmail.com), 4000 Central Florida Blvd., Orlando, FL 32816, and **Gary Richardson** (gary.richardson@ucf.edu), 4000 Central Florida Blvd., Orlando, FL. *Convergence Space Actions.* Preliminary report.

Suppose that a convergence monoid S acts continuously on a convergence space X. It is shown that if Y is any strict regular compactification of X, then there exists an associated Cauchy structure on X such that the action of S on X can be continuously extended to Y iff the action of S on X is Cauchy continuous. Moreover, continuous actions on convergence ordered spaces are studied. In this case, the action is required to be order preserving. Continuously extending the action to an order preserving action on a compactification is investigated. (Received September 05, 2013)

1096-54-545 **Daniel Reid Irvine***, dirvine@nd.edu, and **Samantha Nicole Petti**, snp1@williams.edu.
Applying the Bracket Polynomial to Multi-Crossing Projections.

The recently defined n-crossing is a singular point in a projection at which n strands cross so that each strand bisects the crossing. We generalize to n-crossing number the classic result of Kauffman, Murasugi, and Thistlethwaite, which relates the span of the bracket polynomial to the double-crossing number of a link, $span\langle K\rangle \leq 4c_2$. In this paper we find the following lower bound on the n-crossing number in terms of the span of the bracket polynomial for any n:

$$\mathrm{Span}\langle K\rangle \leq \left(\left\lfloor \frac{n^2}{2}\right\rfloor + 4n - 8\right) c_n(K).$$

(Received September 05, 2013)

1096-54-550 **Ashley Weber*** (weberae@umich.edu). *Bounds on the Übercrossing and Petal Number of Knots.*

A multi-crossing is a crossing in a projection of a knot with n strands of the knot passing straight through it. We consider projections with just one multi-crossing. It is known that every knot has such a projection, called an übercrossing projection, and therefore a well-defined übercrossing number, which is the minimum n for such a projection. We also consider projections with a single multi-crossing such that there are no loops contained within other loops, that we call petal projections. The petal number of a knot is the number of loops of the minimal petal projection of the knot. We investigate the übercrossing number and petal number and how it relates to other knot invariants. (Received September 05, 2013)

1096-54-818 **Yaxi Gao*** (ygao@hmc.edu), Department of Mathematics, Harvey Mudd College, Claremont, CA 91711, **Eric Stucky**, Department of Mathematics, Harvey Mudd College, Claremont, CA 91711, and **Francis Edward Su**, Department of Mathematics, Harvey Mudd College, Claremont, CA 91711. *The Krasnosel'skii Zero Theorem.*

We develop a combinatorial proof of the Krasnosel'skii Zero Theorem which shows the existence of a zero of a continuous map from the n-ball to R^n satisfying a particular boundary condition: that the inner product of any point on the boundary with its image is non-negative. Our proof builds a direct connection to Sperner's Lemma and produces an algorithm for approximating zeros. It also suggests a promising way to weaken the boundary condition. (Received September 12, 2013)

1096-54-903 **Shing S So*** (so@ucmo.edu). *Nets and Upper and Lower Semi-Continuities.*

Let S be a net of sets with domain D and t be a net with domain E. Then t is called an $\in$-*subnet of* S, denoted by $t \leq_{\in} S$, if for each $n \in D$, there exists a $m \in E$ so that for each $p \geq m$ there is a $q \geq n$ such that $t_p \in S_q$. Similarly, $S \leq_{\ni} t$ means that for each $m \in E$, there exists a $n \in D$ so that for each $q \geq n$, there exists a $p \geq m$ such that $t_q \in S_p$. Furthermore, t is called a *reversible* $\in$-*subnet of* S if $t \leq_{\in} S$ and $S \leq_{\ni} t$.

In this paper, we discuss the upper and lower semi-continuities of multifunctions by means of $\in$-subnets and reversible $\in$-subnets. (Received September 11, 2013)

1096-54-1241 **Orsola A Capovilla-Seale*** (ocapovilla@brynmawr.edu) and **Sicong C Zhang**. *The crossing spectrum of knots and the additivity of multi-crossing numbers under composition.*

Traditionally, knots have been tabulated according to their crossing number, which is the least number of crossings in any projection of the knot. Recently, these traditional crossings have been extended to n-crossings, where n strands of the knot intersect in the projection. Hence by minimizing the number of n-crossings, we can define a sequence of crossing numbers for every knot that we call the crossing spectrum. We will discuss the computation of these numbers for various knots. Furthermore we investigate how the n-crossing number behaves under composition. (Received September 13, 2013)

1096-54-1410 **Molly A. Moran*** (mamoran@uwm.edu). *Generalizing Group Boundaries.*

The rich study of boundaries of CAT(0) and hyperbolic groups led M. Bestvina to formalize the concept of a group boundary by defining a Z-structure on a group. In his original definition, a Z-structure on a group G is a pair of spaces $(\hat{X}, Z)$ where $\hat{X}$ is a compact ER, Z is a Z-set in $\hat{X}$, G acts by covering transformations on $X = \hat{X} - Z$, and the collection of G-translates of a compact set in X satisfies a nullity condition in $\hat{X}$. There are several ways we can modify this definition in hopes of extending the theory of group boundaries to a more extensive collection of groups. We will discuss some of these modifications, their implications, and what results, obtained from the original definition, may be extended to the modified cases. (Received September 15, 2013)

1096-54-1453 **Andrew Joseph Dudzik***, adudzik@math.berkeley.edu. *Classical and nonarchimedean spaces.*

We describe and generalize rigid analytic spaces using the language and theory of locales. In this setting, we compare the following constructions: Tate's G-topologies, Huber's adic spaces, Raynaud's formal schemes, Berkovich's Gelfand-type spectra, and Temkin's theory of reductions—as well as analogues for real manifolds. (Received September 15, 2013)

1096-54-1542 **Eva Colebunders** and **Frederic Mynard***, Mathematical Sciences, POBOX 8093, Georgia Southern University, Statesboro, GA 30460, and **William Trott**. *Regularity, function spaces and contractive extensions in Convergence Approach Spaces.*

Two classical results characterizing regularity of a convergence space in terms of continuous extensions of maps on one hand, and in terms of continuity of limits for the continuous convergence on the other, are extended to convergence-approach spaces. Characterizations are obtained for two alternative extensions of regularity to convergence-approach spaces: regularity and strong regularity. The results improve upon what is known even in the convergence case. On the way, a new notion of strictness for convergence-approach spaces is introduced. (Received September 16, 2013)

1096-54-1565 **Michael Barr*** (barr@math.mcgill.ca), Dept. Math. and Stats., 805 Sherbrooke W, Montreal, QC H3a 2K6, Canada, **John F. Kennison** (jkennison@clarku.edu), Department of Mathematics and Comp Sci, Clarke University, Worcester, MA 01610, and **Robert Raphael** (raphael@alcor.concordia.ca), Dept. Math. and Stats., Concordia University, Montreal, QC H4B 1R6, Canada. *The limit closure of metric spaces in uniform spaces.*

Say that a net $\{x_i\}$ in a uniform space X is strongly Cauchy if for every pseudometric d on X, the net $\{d(x_i, x_j)\}$ is eventually 0. James Cooper conjectured and we proved that a separated uniform space is a limit of metric spaces iff every strongly Cauchy net converges. (Received September 16, 2013)

1096-54-1655 **Erik A Insko*** (einsko@fgcu.edu) and **Rolland Trapp** (rtrapp@csusb.edu). *Supercoiled Tangles and Stick Numbers of 2-Bridge Links.*

Utilizing both twisting and writhing, we construct integral tangles with few sticks, leading to an efficient method for constructing polygonal 2-bridge links. Let L be a two bridge link with crossing number c, stick number s, and n tangles. It is shown that $s \leq \frac{2}{3}c + 2n + 3$. We also show that if $c > 12n + 3$, then minimal stick representatives do not admit minimal crossing projections. (Received September 16, 2013)

1096-54-1758 **James P. Kelly*** (j_kelly@baylor.edu), Department of Mathematics, Baylor University, One Bear Place #97328, Waco, TX 76798-7328. *Inverse Limits with Irreducible Set-Valued Functions.*

Given a continuum X, 2^X denotes the set of compact subsets of X. If $\mathbf{X} = (X_i)_{i=1}^{\infty}$ is a sequence of continua, and $\mathbf{F} = (F_i)_{i=1}^{\infty}$ is a sequence of upper semi-continuous set-valued functions where for each $i \in \mathbb{N}$, $F_i : X_{i+1} \to 2^{X_i}$, then the inverse limit of the pair $(\mathbf{X}, \mathbf{F})$ is the set

$$\varprojlim(\mathbf{X}, \mathbf{F}) = \{\mathbf{x} \in \prod_{i=1}^{\infty} X_i : x_i \in F_i(x_{i+1}) \text{ for all } i \in \mathbb{N}\}.$$

We will develop a definition for a class of set-valued functions which will be called irreducible functions, and we will demonstrate that these functions can be used to obtain an indecomposable continuum as an inverse limit. In addition, sufficient conditions will be established for two such inverse limits to be homeomorphic. Our focus will be primarily on indecomposable functions on $[0, 1]$, a class of functions which includes all open mappings other than homeomorphisms. The inverse limits of open mappings on $[0, 1]$ were classified by William Thomas Watkins in 1980, and the results we will discuss build on his results and expand the class of functions to which they apply. (Received September 16, 2013)

1096-54-2351 **Casey Lynn Sherman*** (caseys@stedwards.edu), 514 Travertine Trail, Buda, TX 78610. *Orbit Structures of Homeomorphisms on Cantor Sets.*

If X is a Cantor set and $T : X \to X$ is a homeomorphism, what possible orbit structures can T have? The question is answered in terms of the orbit spectrum of T. (Received September 17, 2013)

1096-54-2457 **Katherine P. Walsh*** (k3walsh@math.ucsd.edu). *Patterns and Stability in the Coefficients of the Colored Jones Polynomial.*

The colored Jones polynomial assigns to each knot a sequence of Laurent polynomials. This talk will focus on the patterns in the coefficients of these polynomials. We will discuss the stabilization and higher-order stabilization of the coefficients, specifically discussing what the second $N - 1$ coefficients of the N-colored Jones polynomial of certain knots stabilize to. We will also look at patterns in the middle coefficients. (Received September 17, 2013)

1096-54-2557 **Andrzej A Szymanski*** (andrzej.szymanski@sru.edu), Department of Mathematics, Slippery Rock, PA 16057. *On L*-operators and around.* Preliminary report.

We analyze some relationships between simplicial structures, L-structures, and L*-spaces. We answer a question of H. Ben-El-Mechaiekh by showing that simplicial structures coincide with L-structures given by 1-continuous operators. We construct a continuous L*-operator on [0,1] that does not permit an L-structure. We show that the unit circle admits no 2-continuous L*-operators. (Received September 17, 2013)

1096-54-2671 **Lena C Folwaczny*** (lena.folwaczny@gmail.com) and **Louis Kauffman**. *The Wriggle Polynomial.*

The Wriggle Polynomial is a virtual knot invariant constructed by assigning a weight at each crossing, the weight being a difference of two virtual linking numbers. The Wriggle Polynomial is equivalent to the Affine Index Polynomial, which is constructed by an integer labeling of arcs in the knot diagram (in the structure of a flat affine biquandle), and then using this integer labeling to assign a weight at each crossing. In this talk we introduce the two polynomials and discuss their ability to distinguish certain types of mutation, their Vassiliev Invariants, and other applications. (Received September 17, 2013)

1096-54-2711 **F H Sturm*** (fhs0001@auburn.edu), Dept. of Mathematics and Statistics, 221 Parker Hall, Auburn, AL 36849. *Homogeneity properties of continua.*

A continuum is a compact connected metric space. A topological space X is said to be homogeneous if for each $x, y \in X$ there is a homeomorphism $h : X \to X$ such that $h(x) = y$. Alternatively, a topological space is said to be homogeneous if it has one orbit under the homeomorphism group.

In this talk, the author will give a brief overview of historical motivations for the study of homogeneity of planar continua, with a focus on pathological continua such as the pseudo-arc. Several generalizations of homogeneity for continua will be introduced (e.g. open homogeneity, continuous homogeneity, and $\frac{1}{n}$-homogeneity), and the author will detail results of his own in addition to results with co-authors. (Received September 18, 2013)

1096-54-2743 **Ellie A Grano*** (ellie.grano@pepperdine.edu), 17311 Castellammare Dr., Apt. 2E, Pacific Palisades, CA 90272. *The pop-switch planar algebra and the Jones-Wenzl projections.* Preliminary report.

The pop-switch planar algebra is a new planar algebra containing the Temperley-Lieb planar algebra. It is motivated by Jones' idea of the "graph planar algebra" of type A_n. Complicated calculations using the graph planar algebra can be done pictorially in this new planar algebra.

The Jones-Wenzl projections are important elements of the Temperley-Lieb planar algebra, yet are very complicated to write down. Viewing the pop-switch planar algebra as a matrix category, the Jones-Wenzl projections are direct sums of very simple diagrams. I will present this new planar algebra and discuss this method of viewing the Jones-Wenzl projections. (Received September 18, 2013)

55 ► Algebraic topology

1096-55-38 **William C Abram*** (wabram@hillsdale.edu), Department of Mathematics, 33 East College Street, Hillsdale, MI 49242. *On the equivariant formal group law of the equivariant complex cobordism ring MU^*_G.*

Using an isotropy separation spectral sequence, Igor Kriz and myself have completed an algebraic description of the equivariant complex cobordism ring MU^*_G for a finite abelian group G. Using this result, we obtain a similarly explicit description of the equivariant formal group law corresponding to MU^*_G with its natural complex orientation. It is hoped that such descriptions may be used to resolve certain open problems about equivariant formal group laws, such as Greenlees' Conjecture that the G-equivariant formal group law corresponding to MU^*_G is algebraically universal for G-equivariant formal group laws. (Received September 12, 2013)

1096-55-298 **Mikael Vejdemo-Johansson*** (mikael@johanssons.org) and **Primoz Skraba**. *A survey of topological data analysis and available toolsets.*

One approach to Big Data is taken by the Topological Data Analysis community in the shape of Complex Data: developing tools for uncovering and analyzing complex geometric descriptors of datasets. This direction of research has been growing for the last 15 years, and has produced a selection of tools that encapsulate techniques from algebraic topology to provide more fine-grained and shape related refinements of clustering methods and geometric modelling tools.

We shall describe the various methods of Topological Data Analysis and the successes so far – including the discovery of a new type of breast cancer, of structure in the space of naturally occurring image patches, and tools for further analysis of soccer and basketball team compositions – and discuss the software tools that are currently available and in use for Topological Data Analysis. (Received August 27, 2013)

1096-55-348 **Pawel Dlotko*** (dlotko@sas.upenn.edu), Department of Mathematics, University of Pennsylvania, Philadelphia, PA. *Computational topology via Discrete Morse Theory.*

During the last decade we witness growing number of applications of computational topology in engineering and science. As a consequence many new concepts, as for instance persistence homology, along with new computational methods has been introduced. In this talk we will present a basics of Discrete Morse Theory (DMT) and introduce a concept of iterated Morse complex. Later we will show that most of the algorithms in computational topology can be obtained by using DMT. To be more precise – we will show, that both (co)homology over a field and persistent (co)homology can be computed using algorithms in DMT. At the end we will interpret standard matrix algorithm to compute persistence and so called reduction algorithms used in homology in the language of DMT. (Received August 29, 2013)

1096-55-458 **Noureen Khan*** (noureen.khan@unt.edu). *New Invariants of Virtual Rational Tangle Moves.*

It was shown that there is no non-trivial rational tangle moves with unknotting property other than crossing change for classical link. Intuitively it should also be true for the case of virtual links. We define the virtual tangle moves generalization of rational tangle moves, and analyze its invariance for virtual knots and links. (Received September 04, 2013)

1096-55-667 **Mustafa Hajij*** (mhajij1@math.lsu.edu), 4243 Burbank Dr Apt 102, Baton Rouge LA, LA 70808. *Skein theory and Andrews-Gordon Identities for the false theta functions.* Preliminary report.

Recent development in the study of the coefficient colored Jones polynomial shows that certain number theoretic q-series show up in the study of the head and tail of the colored Jones polynomial. We give an intuitive method to study and compute the tail of the colored Jones polynomial for a large class of links and we use skein theoretic techniques to Andrews-Gordon Identities for the false theta identities. (Received September 12, 2013)

1096-55-708 **Brittany Terese Fasy*** (bfasy@tulane.edu), Department of Computer Science, Tulane Universi, 6823 St. Charles Ave, New Orleans, LA 70118. *The Intersection of Statistics and Topology.* Preliminary report.

Persistent homology is a method for probing topological properties of point clouds and functions. The method involves tracking the birth and death of topological features as one varies a tuning parameter. Features with short lifetimes are informally considered to be topological noise. I will present some statistical ideas relating to persistent homology; in particular, deriving confidence intervals that allow us to separate topological signal from topological noise. This is joint work with Sivaraman Balakrishnan, Fabrizio Lecci, Alessandro Rinaldo, Aarti Singh, and Larry Wasserman. (Received September 09, 2013)

1096-55-773 **Keith Penrod*** (keith.penrod@gmail.com). *Big Homotopy Theory.*

Cannon and Conner developed the theory of "big fundamental groups." This is meant to expand on the notion of fundamental group and is a powerful tool that can be used for distinguishing spaces that are not distinguishable using the fundamental group. Turner proved several classical results, such as covering theory and Seifert-VanKampen for big fundamental groups. The purpose of this paper is to expand on the the theory, to refine the definitions, and to give more examples. Also, in this paper, we define big higher homotopy groups analogous to the way classical higher homotopy groups are defined. (Received September 10, 2013)

1096-55-850 **Nicholas D Nguyen*** (nicholas.nguyen@uky.edu). *The adjoint action of a homotopy-associative H-space on its loop space.* Preliminary report.

We define the adjoint action of a homotopy associative H-space on its loop space, generalizing the definition by Kono and Kozima for a Lie group (from Kono, Kozima, 1993). We proceed to use this generalized adjoint action to characterize homotopy associative H-spaces whose homology over $\mathbb{F}_p$ is a commutative ring, generalizing a result of Iwase (from Iwase, 1997). (Received September 10, 2013)

1096-55-1014 **Kristen Luise Mazur*** (mazurk@lafayette.edu). *Additional Structure on the Category of Mackey Functors.*

The stable homotopy groups of a G-spectrum are Mackey functors, and the zeroeth stable homotopy group of a commutative G-ring spectrum has the extra structure of a Tambara functor. However, while Mackey functors and Tambara functors make frequent appearances in equivariant stable homotopy theory, much of their underlying algebra remains mysterious. I will discuss a new structure on the category of Mackey functors such that Tambara functors are commutative algebra-like objects. Moreover, the advantage to this new structure is that it is concrete and computable. (Received September 12, 2013)

1096-55-1028 **Walter Zhen Cai*** (wzc2@cornell.edu), 408 Dryden Rd., APT 2, Ithaca, NY 14850. *On the optimization of 1-cycle persistence under the Vietoris-Rips complex.*

Given a finite discrete point set $X \subset \mathbb{R}^n$ and distance parameter δ, we may generate the Vietoris-Rips Complex $R_\delta(X)$; the simplicial complex where a simplex $[x_i]_{i\in I} \in R_\delta(X)$ if $|x_i - x_j| \leq \delta$ for all $i, j \in I$. Given arbitrary 1-cycle σ appearing in the Rips Complex, we may define the the birth and death of σ as $\alpha = \min(\delta : \sigma \in C_1(R_\delta(X)))$ and $\gamma = \min(\delta : \sigma \equiv 0 \in H_1(R_\delta(X)))$ respectively.

We seek to maximize γ with respect to α. In order to do so we consider a specific class of finite point sets $X = \{x_i\}_{0\leq i\leq n}$ where the cycle in question is $\sigma = \sum_{i=0}^{n-1}[x_i, x_{i+1}] + [x_n, x_0]$. We conjecture a possible optimal configuration occurring when the vertices of X are equally spaced on the circle. Our algorithms focus on the manipulation of the original X, incrementally increasing γ while maintaining a constant α. These processes operate by finding subsets of X and through reflection and angular splitting, spread out the vertices in the pursuit of a more circular distribution. (Received September 12, 2013)

1096-55-1067 **Donald M Larson*** (dml34@psu.edu). *The Adams-Novikov E_2 term for $Q(2)$ at the prime 3.*

In this talk we will discuss a computation of the Adams-Novikov E_2 term for the spectrum $Q(2)$. This spectrum is built using degree 2 isogenies of elliptic curves, and is closely tied to the 3-primary $K(2)$-local sphere. We will also examine potential connections between our computation and algebraic Greek letter families in the Adams-Novikov spectral sequence for the 3-local sphere. (Received September 12, 2013)

1096-55-1271 **Yifei Zhu*** (zyf@math.northwestern.edu). *Power operation calculations in elliptic cohomology.*

One question in homotopy theory is to construct and compute stable power operations on elliptic cohomology theories. As a particular instance, for E a Morava E-theory spectrum of height 2, its algebra of power operations has the structure of a graded twisted bialgebra satisfying a Frobenius congruence. For the K(1)-localization of E, its algebra of power operations has a single generator over the coefficient ring. We illustrate this structure and provide explicit formulas by doing calculations, at the prime 3, with moduli of elliptic curves. (Received September 14, 2013)

1096-55-1361 **Elizabeth Munch*** (liz@ima.umn.edu). *Extending Statistical Methods to Computational Topology.*

The past decade has seen great strides in the theoretical aspects of Computational Topology, particularly with the use of Persistent Homology. As the theory grows deeper, so too does the number of interesting applications for the theory, including protein structure, neuroscience, orthodontia, gene expression, and signal analysis. Since these new applications come with large and noisy data sets, care must be taken to define the "average" topological features. In this talk, we will discuss methods for defining the mean of a set of persistence diagrams, and how this can be used to better understand the structure of large and noisy data sets. This work is joint with Katharine Turner, Paul Bendich, Sayan Mukherjee, Jonathan Mattingly, and John Harer. (Received September 15, 2013)

1096-55-1394 **Graham C. Denham** (gdenham@uwo.ca), Department of Mathematics, University of Western Ontario, London, ON N6A 5B7, Canada, **Alexander I. Suciu*** (a.suciu@neu.edu), Department of Mathematics, Northeastern University, Boston, MA 02115, and **Sergey Yuzinsky** (yuz@uoregon.edu), Department of Mathematics, University of Oregon, Eugene, OR 97403. *Abelian duality and propagation of resonance.* Preliminary report.

We revisit and generalize a result of Eisenbud, Popescu, and Yuzvinsky, which says that the resonance varieties of a hyperplane arrangement complement propagate. It turns out that the topological underpinning for this phenomenon is a certain abelian duality property, coupled with the minimality property enjoyed by arrangement complements and related spaces, such as Cohen–Macaulay toric complexes. The key ingredient in the proof is a general, cohomological vanishing result for spaces that admit suitable covers. (Received September 15, 2013)

1096-55-1516 **David White*** (dwhite03@wesleyan.edu), Wesleyan University Department of Mathematics, Exley Science Tower, Room 655, 265 Church Street, Middletown, CT 06457. *Bousfield Localization and Commutative Monoids.*

Localization is a fundamentally important tool in mathematics. Constructing the localization of a category at a given class of maps leads naturally to the notion of a model category. Bousfield localization is a method of localizing further by turning a given class of maps into weak equivalences. In this talk we will give conditions on a monoidal model category and on the class of maps being localized so that the Bousfield localization preserves strict commutative monoids.

This problem was motivated by an example due to Mike Hill which demonstrates that for the model category of equivariant spectra, even very nice localizations can fail to preserve strict commutative monoids. A recent theorem of Hill and Hopkins gives conditions on the localization to prohibit this behavior. When we specialize our general machinery to the equivariant spectra we recover this theorem. En route to solving the localization problem we introduce an axiom which guarantees us that commutative monoids inherit a model structure. If there is time we will discuss a generalization which allows preservation of structure over arbitrary operads, and relate this to the situation of algebras in equivariant spectra over equivariant operads. (Received September 16, 2013)

1096-55-1526 **Tobias Barthel** (tbarthel@math.harvard.edu) and **Martin Frankland*** (mfrankla@uwo.ca). *Completed power operations for Morava E-theory.*

Morava E-theory is an important cohomology theory in chromatic homotopy theory. Using work of Ando, Hopkins, and Strickland, Rezk described the algebraic structure found in the homotopy of $K(n)$-local commutative E-algebras via a monad on E_*-modules that encodes all power operations. However, the construction does not see that the homotopy of a $K(n)$-local spectrum is L-complete (in the sense of Greenlees-May and Hovey-Strickland). We improve the construction to a monad on L-complete E_*-modules, and discuss some applications. (Received September 16, 2013)

1096-55-1558 **Mehdi Khorami*** (khoramim@easternct.edu), 83 Windham St, Willimantic, CT 06226. *Higher Chromatic Analogues of Twisted K-theory.*

Let R_n denote the homotopy fixed point spectrum $E_n^{hS\mathbb{G}_n}$, where $S\mathbb{G}_n$ is the kernel of the determinant homomorphism $\det : \mathbb{G}_n \to \mathbb{Z}_p^\times$ with $\mathbb{G}_n$ being the Morava group. Here E_n denotes the n-th Morava E-theory. We show that for a $K(n)$-local space X equipped with a $K(\mathbb{Z}_p, n+1)$-bundle $P \to X$, the P-twisted R_n-theory of X, $R_{n*}(X,P)$, is defined and there exist a "universal coefficient" isomorphism

$$R_{n*}(X,P) \cong R_{n*}(P) \otimes_{R_{n*}(K(\mathbb{Z}_p,n+1))} \mathbb{R}_{n*}.$$

This extends an analogues result on twisted K-theory in the $K(n)$-local category. (Received September 16, 2013)

1096-55-1645 **Marcy Robertson*** (mrober97@uwo.ca), **Philip Hackney** and **Donald Yau**. *Models for infinity prop(erad)s.*

We give a brief introduction to colored props and their ilk. We then propose ways of encoding the notion of up-to-homotopy prop. (Received September 16, 2013)

1096-55-1661 **Kerry M. Luse*** (lusek@trinitydc.edu) and **Mark Kidwell** (mek@usna.edu). *The role of spinners in determining clock number.* Preliminary report.

The clock number of a knot defined by Y. Abe is determined by the height of the lattice of states between the clocked and counterclocked states of a knot universe as defined in Kauffman's Formal Knot Theory. Abe characterizes knots which have clock number, $p(K)$, equal to the crossing number, $C(K)$, of the knot.

Expanding on Abe's work, we focus on a specific type of vertex in a knot universe which we call "spinners." A spinner vertex is a vertex such that each of its four incident edges supports at least one clock move.

We conjecture that knots with exactly one spinner vertex have $p(K) = C(K) + 1$ and we give a particular characterization of knots of this type. Furthermore, we will show that minimizing the number of spinner vertices in a diagram does not necessarily minimize the clock number of the knot. (Received September 16, 2013)

1096-55-1741 **Jonathan A Campbell*** (jcampbell@math.utexas.edu). *Topological Hochschild Homology and Koszul Duality.*

Topological Hochschild Homology (THH) is an important invariant that comes up in both algebraic K-theory computations and topological quantum field theories. In this talk I'll present a duality for THH of Koszul dual E_1-algebras. This duality has possible applications for computations, and is also the shadow of a conjectured richer structure for field theories. (Received September 16, 2013)

1096-55-1776 **Anna Marie Bohmann*** (bohmann@math.northwestern.edu), Department of Mathematics, 2033 Sheridan Road, Evanston, IL 60208, and **Angelica M. Osorno** (aosorno@reed.edu), Department of Mathematics, 3203 E Woodstock Blvd, Portland, OR 97202. *An equivariant infinite loop space machine.*

An equivariant infinite loop space machine should turn categorical or algebraic data into genuine G-spectra. While infinite loop space machines have been a crucial part of homotopy theory for decades, equivariant versions are in early stages of development. I will describe joint work with A. Osorno in which we build an equivariant infinite loop space machine that starts with diagrams of categories on the Burnside category and produces a genuine G-spectrum via the work of Guillou–May. This machine readily applies to produce Eilenberg–MacLane spectra for Mackey functors and topological K-theory. (Received September 16, 2013)

1096-55-1809 **Austin J. Mack*** (austinjmack@gmail.com). *The Meaning Behind the Coefficients of the sl_2 Weight System of Chord Diagrams.*

After Vassiliev introduced a natural filtration in the space of finite order knot invariants, others suggested a construction of a weight system from a Lie algebra. This work by many, lead to the development of the sl_2 weight system, which takes a chord diagram to a polynomial. It has been seen with a normalization of the chromatic polynomial of a graph we achieve non-negative coefficients with a simple combinatorial meaning. The coefficients represent the number of ways to split the set of vertices of the graph into a number of independent sets. Here we will be investigating a similar relationship between the chord diagrams of knots and the sl_2 weight system. We search to find these coefficients and the combinatorial meaning behind them, relating to their corresponding chord diagram. (Received September 16, 2013)

1096-55-1859 **Ayman Mohammad Almomany*** (almom1am@cmich.edu), Department of Mathematics, Central Michigan University, Mount Pleasant, MI 48859, and **Brad Safnuk**. *Intersection numbers on moduli spaces of curves through topological recursion.*

This paper explores the relationships between the plane algebraic curve and intersection numbers of tautological classes on moduli spaces of curves. The link is provided by Eynard and Orantin's theory of topological recursion, which associates to any plane algebraic curve an infinite family of invariants. Due to work of Eynard, these invariants are closely related to intersection numbers on moduli spaces of curves, and in the present work we make the calculations explicit. Of particular interest is that we find 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, 2013)

1096-55-1886 **Graham Denham*** (g.c.denham@gmail.com), Department of Mathematics, University of Western Ontario, London, Ontario N6A5B7, Canada, **Alexander I Suciu**, Department of Mathematics, Northeastern University, Boston, MA 02115, and **Sergey Yuzvinsky**, Department of Mathematics, University of Oregon, OR 97403. *Combinatorial covers and vanishing cohomology.* Preliminary report.

We construct a combinatorial mechanism for proving cohomological vanishing results on certain classes of spaces, by means of a Mayer-Vietoris-type spectral sequence. The spaces include complex hyperplane complements, their De Concini-Procesi compactifications, complements of torus arrangements, and certain generalised moment-angle complexes. This builds on work of Davis, Januszkiewicz, Leary, and Okun. In particular, we generalize classical vanishing results originating in a paper of Esnault, Schechtman, and Vieweg. (Received September 16, 2013)

1096-55-2048 **Mike Hill*** (mikehill@virginia.edu). *The Kervaire invariant one problem.*

This talk will be about the Kervaire invariant one problem in algebraic topology. (Received September 17, 2013)

1096-55-2049 **John Lind*** (jlind@math.jhu.edu). *Equivariantly Twisted Cohomology Theories.*

Twisted K-theory is a cohomology theory whose cocycles are like vector bundles but with locally twisted transition functions. If we instead consider twisted vector bundles with a symmetry encoded by the action of a compact Lie group, the resulting theory is equivariant twisted K-theory. This subject has garnered much attention for its connections to conformal field theory and representations of loop groups. While twisted K-theory can be defined entirely in terms of the geometry of vector bundles, there is a homotopy-theoretic formulation using the language of parametrized spectra. In fact, from this point of view we can define twists of any multiplicative generalized cohomology theory, not just K-theory. The aim of this talk is to explain how this works, and then to propose a definition of equivariant twisted cohomology theories using a similar framework. The main ingredient is a structured approach to multiplicative homotopy theory that allows for the notion of a G-torsor where G is a grouplike A_∞ space. (Received September 17, 2013)

1096-55-2057 **Enxin Wu*** (ewu24@uwo.ca). *A Homotopy Theory of Diffeological Spaces.*

This talk will be about homotopy theory of diffeological spaces. (Received September 17, 2013)

1096-55-2067 **Carolyn M. Yarnall*** (yarnallc@wabash.edu), Dept. of Mathematics & CS, Wabash College, 301 W. Wabash Ave, Crawfordsville, IN 47933. *The Slice Tower and Suspensions.* Preliminary report.

The slice filtration is a filtration of equivariant spectra developed by Hill, Hopkins, and Ravenel in their solution to the Kervaire Invariant One Problem. After briefly discussing some properties of the filtration, I will present the slice towers of $\Sigma^n H\underline{\mathbb{Z}}$ where the group G is a cyclic p-group. I will highlight the patterns we see in this context by displaying a few specific examples. (Received September 17, 2013)

1096-55-2069 **Mona Merling*** (mmerling@math.uchicago.edu). *Equivariant algebraic K-theory.* Preliminary report.

In the early 1980's, Dress and Kuku, and Fiedorowicz, Hauschild and May introduced space level equivariant versions of the plus and Q constructions in algebraic K-theory. However, back then, the methods did not allow for nontrivial group action on the input ring or category. We generalize these definitions to the case in which a finite group G acts nontrivially on a ring (or an exact or Waldhausen category) and we show how to construct a genuine equivariant K-theory spectrum with good properties from a G-ring. An example of interest is that of a Galois extension.

The equivariant constructions rely on finding categorical models for classifying spaces of equivariant bundles (a joint project with Guillou and May) and the use of equivariant infinite loop space machines such as the one developed by Guillou and May, or the equivariant version of Segal's machine. The comparison of these machines, which will allow their interchangeable use in algebraic K-theory constructions, is a joint project with May and Osorno. New ideas are needed since, among other things, the comparison theorem of May and Thomason fails equivariantly. (Received September 17, 2013)

1096-55-2082 **Johanna Stromberg*** (johanna.strmbrg@gmail.com). *On Braids and the Jones Polynomial.* Preliminary report.

In V.G. Turaev's 1988 paper 'The Yang-Baxter equation and invariants of links' so-called enhanced Yang-Baxter operators are introduced, consisting of a Yang-Baxter operator $R : V^{\otimes 2} \to V^{\otimes 2}$, an isomorphism $\mu : V \to V$ and α, β invertible elements of V. These are such that

(1) $\mu \otimes \mu$ commutes with R

(2) $Sp_2(R \circ (\mu \otimes \mu)) = \alpha\beta\mu$ and $Sp_2(R^{-1} \circ (\mu \otimes \mu)) = \alpha^{-1}\beta\mu$

Together they define a braid invariant $T_s(\sigma) = \alpha^{-w(\sigma)}\beta^{-n} Sp(b_R(\sigma) \circ \mu^{\otimes n})$, where $w(\sigma)$ is the writhe of the braid, n is the order of the braid and Sp is the standard trace. Explicit constructions are given for the EYB-operators. This paper explicitly demonstrates explicitly that $T_s(\sigma)$ with the given constructions is yield the same polynomial as the construction of the Jones polynomial through Kauffman brackets. (Received September 17, 2013)

1096-55-2141 **Sean M Tilson*** (stilson@kth.se). *Power Operations and Commutative Ring Spectra.*

We will compute the action of the Dyer-Lashof algebra on relative smash products using the multiplicative structure of the Künneth spectral sequence. We will then interpret such operations in terms of different possible E_∞-structures. We will end with an application of these computations to give a non-existence result for E_∞-complex orientations of certain ring spectra. (Received September 17, 2013)

1096-55-2298 **Justin Noel***, justin@nullplug.org. *Moduli spaces of algebra structures.* Preliminary report.

To construct a homotopy coherent multiplication one can inductively construct partial multiplications, called A_n-structures, via obstruction theory. We generalize Angeltveit's work on this obstruction theory for the A_∞-operad to symmetric operads such as the E_∞-operad. More precisely, we construct an obstruction-theoretic spectral sequence computing the homotopy groups of the moduli space of algebra structures (in the ∞-categorical sense) on a space. This work depends on a theory of generalized topological Reedy categories, which the author is developing with Moritz Groth. (Received September 17, 2013)

1096-55-2365 **Mark Behrens*** (mbehrens@math.mit.edu), **Kyle Ormsby**, **Nathanial Stapleton** and **Vesna Stojanoska**. *tmf cooperations.* Preliminary report.

The groups bo_*bo have a been long understood by the work of Adams, Mahowald, Milgram, and others. The Adams perspective is based on numerical polynomials, wheras the Mahowald perspective is based on a splitting of bo_*bo into the bo-homology of integral Brown-Gitler spectra.

Following a program initiated by Mahowald, we will discuss the analogous approach at odd primes. We will explain how to relate Mahowald's bo-Brown-Gitler spectrum approach to Laures' 2-variable modular forms, and a third geometric approach involving isogenies of elliptic curves. (Received September 17, 2013)

1096-55-2450 **Matthew D Overduin*** (004494229@mycoyote.edu), PO Box 292556, Phelan, CA 92329. *Three-Variable Bracket Polynomial for Two-Bridge Knots.* Preliminary report.

We derive recursive formulas for the three-variable bracket polynomial of a twist connected to a tangle and for a twist that connects to a tangle in two places. We use these formulas to derive the three-variable bracket polynomial for two-bridge knots. From this, we determine that the highest exponent of d is equal to the crossing number minus the twist number when the two-bridge knot has no twists with single crossings. We also state a theorem that allows one to determine the number of states corresponding to the maximal exponent of d for a two bridge knot not containing any twist with single crossings. (Received September 17, 2013)

1096-55-2535 **Michael A Abel*** (maabel@email.unc.edu) and **Lev Rozansky**. *A new grading in HOMFLY-PT homology via virtual crossings.* Preliminary report.

In 2005 Khovanov and Rozansky defined a triply-graded homology theory which categorifies the HOMFLY-PT polynomial. Later Khovanov showed that this homology theory could be reconstructed using Rouquier complexes of Soergel bimodules. There exists a filtration of Soergel bimodules into bimodules representing virtual crossings, or standard bimodules. By passing to a nested derived category and representing Soergel bimodules as convolutions of virtual crossings, we show that this filtration induces a fourth independent grading on HOMFLY-PT homology. (Received September 17, 2013)

1096-55-2588 **Benson Farb*** (farb@math.uchicago.edu), Math Dept., Eckhart Hall, University of Chicago, 5734 S. University Ave., Chicago, IL 60614. *Braids, homology and polynomials : an emerging pattern in algebra and topology.*

Natural mathematical objects often occur in families parametrized by the natural numbers. Examples include the group of invertible $n \times n$ integer matrices (and its congruence subgroups), spaces of configurations of n distinct points on a manifold, and various spaces of polynomials in n variables. It was recently discovered that certain numerical invariants attached to these sequences, such as Betti numbers and dimensions, actually "stabilize" to a polynomial in n once n is big enough.

In this talk I will try to explain what is happening here, tell the story of how it was discovered, and expose a single mechanism responsible for the common behavior in these very different examples. Along the way we will see this stability phenomenon reflected in the combinatorial stability of counts of degree n polynomials over finite fields. This is joint work with (various linear combinations of) Tom Church, Jordan Ellenberg and Rohit Nagpal. (Received September 17, 2013)

1096-55-2614 **Mayra Lopez*** (mayralopez4@my.unt.edu) and **Noureen Khan**. *On Virtual Group Presentation.*

The fundamental groups of a knot complement is a strong invariant of classical knots. In this paper we extend the notion of fundamental groups for virtual knots. We introduce virtual operator "T" for a virtual crossing and calculate Wirtinger relations for virtual link diagrams. Moreover; we present combinatorial approach for virtual knot groups to show that virtual crossings have impact on the constructed objects. (Received September 17, 2013)

1096-55-2615 **Irina Bobkova*** (bobkova@math.northwestern.edu). *Towards a resolution of the spectrum $E^{h\mathbb{S}_2^1}$ at the prime 2.*

Chromatic homotopy theory uses the algebraic geometry of formal groups to organize calculations. In particular, at each prime p there exists a series of homology theories $K(n)$, called Morava K-theories and we can reconstruct the homotopy type of p-local spectra from their Morava K-theories localizations. When $n = 2$ a lot of information can be derived from the action of a certain profinite group, called the Morava stabilizer group, on the Lubin-Tate theory. We can form homotopy fixed points spectra with respect to this action and compute their homotopy groups using continuous group cohomology. We discuss a generalization to prime 2 of work of Goerss-Henn-Mahowald-Rezk on constructing a tower of fibrations, whose inverse limit is the spectrum $E_2^{h\mathbb{S}_2^1}$, a "half" of the K(2)-local sphere. The successive fibers of the tower are homotopy fixed points spectra with respect to specific finite subgroups of the Morava stabilizer group. This makes the computations accessible as it is possible to make very detailed calculations with finite subgroups using the theory of elliptic curves. (Received September 17, 2013)

1096-55-2786 **Lek-Heng Lim*** (mkl@ams.org). *Hodge operator in data analysis.*

Applications of discrete Hodge theory on simplicial complexes to problems in game theory, graphics, imaging, learning, ranking, robotics, voting, and sensor networks. (Received October 15, 2013)

57 ► Manifolds and cell complexes

1096-57-249 **Alissa S. Crans*** (acrans@lmu.edu), **Sandy Ganzell** and **Blake Mellor**. *The Forbidden Number.*

Every classical or virtual knot is equivalent to the unknot via a sequence of extended Reidemeister moves and the so-called forbidden moves. The minimum number of forbidden moves necessary to unknot a given knot is a new invariant we call the forbidden number. We relate the forbidden number to several known invariants, and calculate bounds for some classes of virtual knots. (pure session) (Received August 23, 2013)

1096-57-337 **Ilesanmi Adeboye*** (iadeboye@wesleyan.edu). *The Area of Projective Surfaces.*

A strictly convex real projective orbifold is a quotient $\mathcal{Q} = \Omega/\Gamma$, where Ω is an open strictly convex set in $\mathbb{RP}^n$ and Γ is a discrete subgroup of $\mathrm{PGL}(n+1,\mathbb{R})$ which preserves Ω. These objects include all hyperbolic manifolds but, in general, are neither Riemannian nor homogeneous. They do posses a natural Finsler metric called the Hilbert metric. The Hilbert metric determines a Hausdorff measure that assigns a Hilbert volume to the orbifolds under consideration. In this talk, I will prove an explicit lower bound for the area of a projective 2-orbifold. This is joint work with Daryl Cooper. (Received August 29, 2013)

1096-57-355 **M Kate Kearney*** (kearney@lsu.edu). *An Obstruction to Knots Bounding Möbius Bands in B^4.*

The relationship between embedded surfaces and their knotted boundaries has been one of the primary topics of knot theory for much of the last half century. While great progress has been made on the oriented case (in particular the theory of knot concordance), development in the non-orientable case has paled in comparison. However, since the advent of Heegaard-Floer theory, new tools and techniques have proven fruitful in application to both problems. This talk focuses on a particular case, namely whether a given knot in the three-sphere can be the boundary of a Möbius band embedded in the four-ball, B^4. We will discuss new examples of knots which do not bound Möbius bands in B^4, and describe how the d-invariant of Heegaard-Floer theory is used as an obstruction to knots bounding Möbius bands in B^4. (Received August 29, 2013)

1096-57-456 **Jin Ho Kwak*** (jinkwak@postech.ac.kr). *Enumeration of orientable coverings of a non-orientable manifold.*

In this talk, we discuss the known V.A. Liskovets problem on the number of orientable coverings over non-orientable manifold with an arbitrary finitely generated fundamental group. The number of cyclic orientable and non-orientable coverings is also discussed. (Received September 03, 2013)

1096-57-555 **Suhyoung Choi*** (schoi@math.kaist.ac.kr), Department of Mathematical Sciences, KAIST, Yuseong-Gu Guseong, Daejeon, 305-701, South Korea. *The classification of radial ends of properly convex real projective orbifolds.* Preliminary report.

Real projective structures on n-orbifolds are useful in understanding the space of representations of discrete groups into $SL(n+1,R)$. A recent work shows that many hyperbolic manifolds deform to manifolds with such structures not projectively equivalent to the original ones. The purpose of this paper is to understand the structures of ends of real projective n-dimensional orbifolds. In particular, we will study ones with the radial ends. These include hyperbolic manifolds with cusps and hyperideal ends. The main techniques are the theory of Fried and Goldman on affine manifolds and the work on Riemannian foliations by Molino, Carrière, and so on. For this, we will need to study the natural conditions on eigenvalues of holonomy representations of ends when these are manageably understandable. We will show that only the concave ends or horospherical ends exist for irreducible properly convex real projective orbifolds under the conditions. We also discuss the ends completed by totally geodesic boundary orbifolds and their duality to radial ends. (Received September 05, 2013)

1096-57-584 **Cagri Karakurt** and **Tye Lidman*** (tlid@math.utexas.edu). *Seifert fibered homology spheres and the Heegaard Floer homology botany problem.*

Using work of Némethi and a refinement by Can and Karakurt, we prove that there exists an algorithm to solve the botany problem for Seifert fibered integer homology spheres. That is, given a $\mathbb{Z}$-graded $\mathbb{Z}[U]$-module, we show that there is an algorithm to determine which Seifert homology spheres have this module as their Heegaard Floer homology (and in particular, that there are only finitely many such Seifert homology spheres). (Received September 06, 2013)

1096-57-650 **sarah-marie belcastro*** (smbelcas@toroidalsnark.net). *Knitting Torus Knots and Links.*

One straightforward way to knit a trefoil knot is to tie a circular knitting needle into an overhand knot and knit a few rounds, as the author did in 2009. How might one knit more complicated knots? Of course, one can tie a circular knitting needle into the desired knot, and one can accomplish this by naively reproducing a knot diagram. Unlike the ease with which one can replicate a knot diagram on paper, it is quite challenging to thread a springy cable along the pattern of a knot diagram without assistance (from extra hands or masking tape). Some types of knots lend themselves to more systematic constructions. In the present work, we describe an algorithmic method for preparing circular knitting needles to create certain infinite families of torus knots and torus links. (Received September 08, 2013)

1096-57-671 **Jozef H. Przytycki*** (przytyck@gwu.edu), Department of Mathematics, George Washington University, Washington, DC 20052. *Polynomial time complexity from Jones polynomial to Khovanov homology.*

We discuss here my (old) work on computational complexity of quotients of the Jones, Homflypt, and 2-variable Kauffman polynomials, and refinement due to D.Vertigan: If we expand the Homflypt polynomial $P_L(a,z) = \sum_m^M P_i(v)z^i$ then $P_i(v)$ can be computed in polynomial time (dynamics programming is used here). We propose to use these results to Khovanov and Khovanov-Rozansky homology and we discuss parts of the homology computable in polynomial time. (Received September 09, 2013)

1096-57-788 **Grant S Lakeland*** (lakeland@illinois.edu) and **Christopher J Leininger**. *Systoles and Dehn surgery for hyperbolic 3-manifolds.*

Given a closed hyperbolic 3-manifold M of volume V, and a link $L \subset M$ such that the complement $M \setminus L$ is hyperbolic, we establish a bound for the systole length of $M \setminus L$ in terms of V. This extends a result of Adams and Reid, who showed that in the case that M is not hyperbolic, there is a universal bound of 7.35534... . As part of the proof, we establish a bound for the systole length of a non-compact finite volume hyperbolic manifold which grows asymptotically like $\frac{4}{3}\log V$. This is joint work with Chris Leininger. (Received September 10, 2013)

1096-57-826 **Richard A Scott*** (rscott@scu.edu). *Nonpositively curved Eulerian cube complexes and reciprocity.*

Let G be the fundamental group of a compact nonpositively curved cube complex Y. With respect to a basepoint x, one obtains an integer-valued length function on G by counting the number of edges in a minimal length edge-path representing each group element. The *growth series of G with respect to x* is then defined to be the power series $G_x(t) = \sum_g t^{|g|}$ where $|g|$ denotes the length of g. Using the fact that G admits a suitable automatic structure, $G_x(t)$ can be shown to be a rational function. We prove that if Y is a manifold of dimension n, then this rational function satisfies the reciprocity formula $G_x(t^{-1}) = (-1)^n G_x(t)$. We prove the formula in a more general setting, replacing the group with the fundamental groupoid, replacing the growth series with the characteristic series for a suitable regular language, and only assuming Y is Eulerian. (Received September 10, 2013)

1096-57-832 **David Auckly*** (dav@math.ksu.edu), Kansas State University, Mathematics Department, Manhattan, KS 66506, and **Hee Jung Kim**, **Paul Melvin** and **Danny Ruberman**. *Stable equivalence of knotted spheres, smooth automorphisms, and positive scalar curvature metrics.*

It is known that homotopy equivalent, simply-connected, smooth 4-manifolds become diffeomorphic after enough stabilizations. Similar results may be stated for knotted 2-spheres, smooth automorphisms, and PSC metrics. In general very little is known about the number of stabilizations required. We will compute the required number of stabilizations in a few cases. (Received September 10, 2013)

1096-57-838 **Jonathan M Bloom*** (jbloom@math.mit.edu) and **John A Baldwin** (john.baldwin@bc.edu). *A bordered monopole Floer theory.* Preliminary report.

I'll discuss work-in-progress with John Baldwin toward constructing a gauge-theoretic analogue of the Fukaya category and monopole Floer theoretic invariants of bordered 3-manifolds. Our construction associates an A_∞ category to a surface, an A_∞ functor to a bordered 3-manifold, and an A_∞ natural transformation to a 4-dimensional cobordism of bordered 3-manifolds. I'll describe how surgery provides a finite set of bordered handlebodies which generate our category. The morphism spaces for this generating set define a finitely generated A_∞ algebra containing Khovanov's H^n algebra. In fact, our approach is strongly motivated by Khovanov's functor-valued invariant of tangles. (Received September 10, 2013)

1096-57-846 **Jennifer Hom*** (hom@math.columbia.edu). *An infinite rank summand of topologically slice knots.* Preliminary report.

Let C_{TS} be the subgroup of the smooth knot concordance group generated by topologically slice knots. Endo showed that C_{TS} contains an infinite rank subgroup, and Livingston and Manolescu-Owens showed that C_{TS} contains a $\mathbb{Z}^3$ summand. We show that in fact C_{TS} contains a $\mathbb{Z}^\infty$ summand. The proof relies on the knot Floer homology package of Ozsváth-Szabó and the concordance invariant ε. (Received September 10, 2013)

1096-57-888 **Moshe Cohen***, Mathematics Department, Technion - Israel Institute of Technology, 3200 Haifa, Israel, and **Meirav Topol Amram**, **Hao Sun**, **Mina Teicher**, **Fei Ye** and **Anna Zarkh**. *New ten-line arrangements: reflections and a notion of distance.*

The authors classify the moduli spaces of all ten-line arrangements, producing a list of eighteen arrangements with disconnected moduli spaces. Some of these potential Zariski pairs can be discarded by a technique which uses combinatorial symmetry to produce a geometric reflection. Furthermore, a notion of distance is given for real arrangements with an application to fundamental groups. (Received September 11, 2013)

1096-57-952 **Stavros Garoufalidis** (stavros@math.gatech.edu), **Craig D. Hodgson** (c.hodgson@ms.unimelb.edu.au), **J. Hyam Rubinstein** (rubin@ms.unimelb.edu.au) and **Henry Segerman*** (segerman@math.okstate.edu). *1-efficient triangulations and the index of a cusped hyperbolic 3-manifold.*

Recent work by Dimofte, Gaiotto and Gukov defi nes the “index” (a collection of Laurent series) associated to an ideal triangulation of an oriented cusped hyperbolic 3-manifold. “Physics tells us” that this index should be a topological invariant of the manifold, not just of the triangulation of it. The problem is that the index is not well de fined on all triangulations. We de fine a class of triangulations of a 3-manifold, depending only on the topology of the manifold, such that the index is well-defi ned and has the same value for each triangulation in the class. A key requirement is that the class of triangulations be connected by local moves on the triangulations, since we can prove invariance of the index under these moves. To achieve this requirement we import a result from the theory of regular triangulations of Euclidean point confi gurations due to Gelfand, Kapranov and Zelevinsky. (Received September 11, 2013)

1096-57-1052 **Paul Seidel*** (seidel@math.mit.edu). *Critical points of complex polynomials from a symplectic viewpoint.*

There is a classical topological theory of isolated critical points of complex polynomials, which includes as a key component the study of their monodromy maps. Since the late 1990s, symplectic topology has matured to the point where it can make meaningful contributions to the subject. We will review some of the classical techniques, and see what new insights the symplectic viewpoint brings with it. (Received September 12, 2013)

1096-57-1083 **Susan M. Abernathy*** (sabern1@tigers.lsu.edu). *The Kauffman bracket ideal for genus-1 tangles.*

Given a compact oriented 3-manifold M in S^3 with boundary, an $(M, 2n)$-tangle $\mathcal{T}$ is a 1-manifold with $2n$ boundary components properly embedded in M. We say that $\mathcal{T}$ embeds in a link L in S^3 if $\mathcal{T}$ can be completed to L by a 1-manifold with $2n$ boundary components exterior to M. The link L is called a closure of $\mathcal{T}$. We define the Kauffman bracket ideal of $\mathcal{T}$ to be the ideal $I_{\mathcal{T}}$ of $\mathbb{Z}[A^{\pm 1}]$ generated by the reduced Kauffman bracket polynomials of all closures of $\mathcal{T}$. If this ideal is non-trivial, then $\mathcal{T}$ does not embed in the unknot. We give an algorithm for computing a finite list of generators for the Kauffman bracket ideal of any $(S^1 \times D^2, 2)$-tangle, also called a genus-1 tangle, and give an example of a genus-1 tangle with non-trivial Kauffman bracket ideal. Furthermore, we show that if a single-component genus-1 tangle $\mathcal{T}'$ can be obtained as the partial closure of a $(B^3, 4)$-tangle $\mathcal{T}$, then $I_{\mathcal{T}} = I_{\mathcal{T}'}$. (Received September 12, 2013)

1096-57-1091 **Razvan Gelca*** (rgelca@gmail.com), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79410, and **Alastair Hamilton**. *Theta functions and topological quantum field theory.*

This talk is about Abelian Chern-Simons theory. We prove the uniqueness of the topological quantum field theory associated to Riemann’s theta functions. (Received September 12, 2013)

1096-57-1124 **Steven Schluchter*** (sas71@gwmail.gwu.edu), Department of Mathematics, The George Washington University, 2115 G St. NW #240, Washington, DC 20052. *Ordinary voltage graphs, pseudosurfaces, and derived graph embeddings: lifting cellular homology.*

Ordinary voltage graph embeddings algebraically and combinatorially encode highly-symmetric embeddings of highly-symmetric graphs in surfaces and pseudosurfaces. We will survey our recent results that partially develop a homological understanding of the encoded embedding that considers specific algebraic and topological properties of the encoding. We will also consider a few infinite families of graphs and and explain the way in which the symmetries of the graphs impact their embeddability in specific surfaces as embeddings encoded by ordinary voltage graph embeddings. (Received September 13, 2013)

1096-57-1174 **J. Scott Carter**, **Atsushi Ishii** and **Masahico Saito*** (saito@usf.edu). *Homology for quandles with partial group operations.* Preliminary report.

Quandle homology theories have been constructed in analogy of group homology. There are quandles in which group operations are partially defined, and the two operations satisfy certain compatibility conditions. We present such structures called multiple conjugation quandles, and propose a homology theory that reflect both operations. Relations to handle-body links are discussed. (Received September 13, 2013)

1096-57-1245 **Changsong Li***, Department of Mathematical Sciences, UTD, Richardson, TX 75080, and **Mieczyslaw K. Dabkowski** (mdab@utdallas.edu), Department of Mathematical Sciences, UTD, Richardson, TX 75080. *Kauffman States of Generalized Crossing.* Preliminary report.

An $m \times n$ generalized crossing $D_{m,n}$ is an $(m+n)$ tangle, in which m strands are placed above n strands. We consider a problem of finding an explicit formula for Kauffman bracket states sum of $D_{m,n}$. In particular, we determine the number of $m+n$ Catalan states that do not appear as the Kauffman states of the generalized crossing, and we find necessary and sufficient condition for the Catalan tangle to be obtained as a Kauffman state of $D_{m,n}$. We relate our results to the problem of finding a closed formula for the product in the Kauffman Bracket Skein Algebra of I-bundle over 3 punctured disk defined by D. Bullock and J. Przytycki. (Received September 13, 2013)

1096-57-1260 **Adam Giambrone*** (giambro1@msu.edu). *Combinatorics of Link Diagrams and Volume.* Preliminary report.

One of the current aims of knot theory is to relate geometric invariants of links, quantum invariants of links, and combinatorial data associated to diagrams of links to each other. In this talk, we will begin with a study of the combinatorics of A-adequate link diagrams whose associated all-A state graphs satisfy a certain two-edge loop condition. From this investigation, we obtain a lower bound on the complexity of the all-A graph that can be expressed in terms of two diagrammatic quantities. By work of Futer, Kalfagianni, and Purcell, such links are usually hyperbolic and the complexity bound actually provides a lower bound on the volume of the link complement (a geometric invariant). This pairs nicely with work of Agol and D. Thurston to give two-sided bounds. Finally, by studying certain plat closures of braids, we are able to express the volume bounds in terms of a single diagrammatic quantity or, alternatively, in terms of a stable coefficient of the colored Jones polynomial (a quantum invariant). (Received September 14, 2013)

1096-57-1266 **Michael Brad Henry*** (mbhenry@siena.edu) and **Dan Rutherford** (drruther@uark.edu). *Ruling polynomials and augmentations over finite fields.*

For any Legendrian link, L, in $(\mathbb{R}^3, \ker(dz - y\,dx))$ we define invariants, $Aug_m(L,q)$, as normalized counts of augmentations from the Legendrian contact homology DGA of L into a finite field of order q where the parameter m is a divisor of twice the rotation number of L. Generalizing a result of Ng and Sabloff for the case $q=2$, we show the augmentation numbers, $Aug_m(L,q)$, are determined by specializing the m-graded ruling polynomial, $R^m_L(z)$, at $z = q^{1/2} - q^{-1/2}$. As a corollary, we deduce that the ruling polynomials are determined by the Legendrian contact homology DGA. (Received September 14, 2013)

1096-57-1342 **Emily R Landes*** (erlandes@gmail.com), Department of Mathematics, Technion – Israel Institute of Technology, 32000 Haifa, Israel. *Linking Nielsen Equivalence with Character Varieties.* Preliminary report.

Determining which generating sets of a given group G are Nielsen equivalent is an ongoing problem in combinatorial group theory that has important applications to low dimensional topology. For the first time we consider this problem from the perspective of character varieties, and as a start we examine fundamental groups of hyperbolic manifolds and their $SL_2(\mathbb{C})$ character varieties $X(G)$. Using González-Acuña and Montesinos-Amilibia's coordinates for $X(G)$, we see a nice correspondence between Nielsen transformations of a generating set for G and smooth automorphisms on the ambient space of $X(G)$. In my talk I will describe the construction, provide details for the figure-8 knot complement, and point out a looming connection with Teichmüller theory and the moduli space of marked genus g curves $\bar{M}_g$. (Received September 15, 2013)

1096-57-1357 **Adam M Lowrance*** (adlowrance@vassar.edu). *Measuring a knot's distance from alternating.* Preliminary report.

A knot invariant $d(K)$ measures a knot's distance from alternating if $d(K)$ is a non-negative integer such that $d(K) = 0$ if and only if K is alternating and such that $d(K_1 \# K_2) \leq d(K_1) + d(K_2)$. We compare and contrast several such distance invariants, including dealternating number, alternation number, alternating genus, Turaev genus, and warping span. (Received September 15, 2013)

1096-57-1389 **Maciej Niebrzydowski*** (mniebrz@gmail.com). *On some ternary algebras in knot theory.* Preliminary report.

We introduce a way to color the regions of a classical knot diagram using ternary operations, so that the number of colorings is a knot invariant. By choosing appropriate substitutions in the algebras that we assign to diagrams, we obtain the relations from the knot group, and from the core group. Using the ternary operator approach, we generalize the Dehn presentation of the knot group to extra loops, and a similar presentation for the core group to the variety of Moufang loops. (Received September 15, 2013)

1096-57-1420 **Stefan Friedl** and **Daniel S Silver*** (silver@southalabama.edu), Department of Mathematics and Statistics, ILB, Mobile, AL 36688, and **Susan G Williams**. *Splittings of knot groups.*

Let K be a knot of genus g. If K is fibered, then it is well known that the knot group $\pi(K)$ splits only over a free group of rank $2g$. We show that if K is not fibered, then $\pi(K)$ splits over non-free groups of arbitrarily large rank. Furthermore, if K is not fibered, then $\pi(K)$ splits over every free group of rank at least $2g$. However, $\pi(K)$ cannot split over a group of rank less than $2g$. The last statement is proved using the recent results of Agol, Przytycki–Wise and Wise. (Received September 15, 2013)

1096-57-1424 **Louis H. Kauffman*** (kauffman@uic.edu), Math UIC, 851 South Morgan Street, Chicago, IL 60607-7045. *Elements of Khovanov Homology.* Preliminary report.

By starting with the categorical chain homotopy approach of Bar-Natan, we show how the Frobenius algebra structures related to Khovanov homology emerge naturally. We then continue the talk with a discussion of the relationship of Khovanov homology with quantum computing and quantum statistics. (Received September 15, 2013)

1096-57-1442 **Carmen L Caprau***, 5245 North Backer Avenue M/S PB 108, Fresno, CA 93740. *On a categorification for the sl(n) polynomial (for n > 3).* Preliminary report.

We use a special type of singular cobordisms, called foams, and a slightly modified version of the MOY state model for the sl(n) link polynomial (for n > 3) to develop an integral cohomology theory corresponding to a rank-n Frobenius extension, which categorifies the sl(n) polynomial. In order to obtain a theory that provides efficient computations, we develop our construction so that it works for tangles, as well.

In this talk we explore our approach to the sl(n) cohomology theory, discuss the results gained, difficulties encountered, and efforts made to overcome them. (Received September 15, 2013)

1096-57-1475 **Adam S Sikora*** (asikora@buffalo.edu), 244 Math Bldg, University at Buffalo, SUNY, Buffalo, NY 14260. *Towards coordinate systems on G-character varieties of surfaces.* Preliminary report.

We will construct a natural family of algebraically independent functions on G-character varieties of closed surfaces for all simple reductive groups G. We will discuss our work towards extending them to coordinate systems on these character varieties. (Received September 15, 2013)

1096-57-1488 **J. Scott Carter** (susandan@mac.com), Dept. of Mathematics and Stat, Mobile, 36688, **Daniel S. Silver** (susandan@mac.com), Mobile, 36688, and **Susan G. Williams*** (swilliams@southalabama.edu). *Links in thickened surfaces and virtual genus.*

We describe two invariants of an oriented link in a closed, orientable thickened surface. The first is a finitely presented operator group in the sense of Krull and Noether, and is a generalization of the Alexander group defined by Silver and Williams for links in S^3. From this we derive a polynomial invariant that generalizes the Alexander polynomial. As an application, we give a lower bound for virtual genus and obstructions to invertibility of virtual links. (Received September 15, 2013)

1096-57-1492 **Patrick Y Chu*** (pyc3@rice.edu) and **Alex D Chichester**. *The Kauffman bracket for Singular Links.* Preliminary report.

The Kauffman bracket is a polynomial invariant for knots and links, giving a simplified method for computing the Jones polynomial. A singular link with n components is an immersion of n circles in three-dimensional space, which admits only finitely many singularities that are all transverse double points. In this talk we extend the Kauffman bracket to singular links by imposing an additional skein relation involving a singular point in a link diagram. We then examine the implications of our approach on extending the Yang-Baxter state model for the Kauffman bracket to singular links.

Most part of this research was conducted during the 2013 Summer REU at California State University, Fresno, under the supervision of Professor Carmen Caprau. (Received September 15, 2013)

1096-57-1514 **Nathan Sunukjian***, nsunukjian@math.sunysb.edu. *Smoothly knotted surfaces in 4-manifolds.*

It is possible for two surfaces in a 4-manifold to be topologically isotopic but not smoothly isotopic. Such surfaces are called *exotically* embedded. In this talk I will describe a new technique for producing families of such surfaces, and show how, without much effort, to make the surfaces smoothly isotopic again. (Received September 16, 2013)

1096-57-1569 **Matt Sequin*** (matt.sequin@rutgers.edu). *Some Results Concerning Quantum Invariants of Links and 3-manifolds.*

In this talk, we will discuss some recent results about 3-manifold and link invariants derived from Hopf algebras. In particular, we will discuss conditions in which the Hennings and Kuperberg invariants are known to be equivalent. We will also discuss some ways to generalize these to produce invariants of tangles and other topological categories. (Received September 16, 2013)

1096-57-1578 **Rachel Roberts*** (roberts@math.wustl.edu). *Taut foliations.* Preliminary report.

I will describe constructions of taut codimension one foliations of 3-manifolds in the context of the Eliashberg-Thurston theorem. (Received September 16, 2013)

1096-57-1669 **Charles D. Frohman** and **Joanna Kania-Bartoszynska*** (jkaniaba@nsf.gov). *The Kauffman bracket skein module of a connected sum of copies of $S^1 \times S^2$.*

We describe the structure of the Kauffman bracket skein module of a 3-manifold which is a connected sum of k copies of the product of a circle with a sphere, where the variable in the Kauffman bracket skein relation is a root of unity. We show how this module is related to the SL(2,C)-characters of the fundamental group of the 3-manifold. (Received September 16, 2013)

1096-57-1672 **R Sean Bowman*** (sean.bowman@okstate.edu) and **Jesse Johnson**. *Bridge numbers of knots in the page of an open book.* Preliminary report.

An open book decomposition of a 3–manifold M consists of a binding L and a bundle map $M \setminus L \to S^1$ such that the preimage of a point in S^1 is the interior of a surface S whose boundary is the link L. Such a surface is called a page of the open book, and we examine knots lying in these surfaces. By studying the action of the map on the arc and curve complex of a page induced by the bundle map, we find knots which have arbitrarily large bridge number with respect to Heegaard splittings of every genus up to $2g(S) - 1$. Several corollaries will be noted. (Received September 16, 2013)

1096-57-1814 **Jennifer E Elder*** (arwenu@mail.fresnostate.edu) and **Elaina K Aceves** (ekaceves@mail.fresnostate.edu). *An invariant for spatial graphs.* Preliminary report.

A spatial graph is an embedding of a graph in three-dimensional space. We construct an invariant for spatial graphs by performing certain replacements at the vertices of a graph diagram, which results in a collection C of arcs and knot/link diagrams. After discarding the arcs, we use known polynomial invariants for knots and links to evaluate the objects in the collection C, and obtain a Laurent polynomial associated with our original spatial graph, which is independent on the embedding type of the graph. Thus our approach yields an invariant for spatial graphs. We discuss some properties of this invariant, including a relationship between the resulting invariant of a spatial graph G and the invariants associated with the two graphs obtained from G by applying the contraction-deletion move in a neighborhood of a vertex of the graph G. (Received September 16, 2013)

1096-57-1818 **Elaina K Aceves*** (ekaceves@mail.fresnostate.edu) and **Jennifer E Elder** (arwenu@mail.fresnostate.edu). *A Yang-Baxter model for specializations of the Kauffman polynomial.* Preliminary report.

Louis Kauffman constructed a Yang-Baxter state model for specializations of the HOMFLY-PT polynomial. Francois Jaeger presented the 2-variable Kauffman polynomial D(K) of an unoriented link K as a weighted sum of HOMFLY-PT polynomials of oriented links associated with the given link K. These constructions show that there is a certain type of Yang-Baxter model for specializations of the Kauffman polynomial D(K), and the goal of this talk is to explore the resulting state model for D(K). (Received September 16, 2013)

1096-57-1838 **Benjamin Cooper*** (cooper.ben.j@gmail.com), **Anna Beliakova** and **Hoel Queffelec**. *Steenrod structures on quantum groups.* Preliminary report.

(joint with A. Beliakova and H. Queffelec) The Steenrod algebra is essential element in the study of the algebraic topology of spaces. The structures which underly the construction of categorified quantum groups are modules over this algebra in a natural way. This observation leads to a study which enriches the categorified quantum groups and associated constructions. In particular, knot homology theories. (Received September 16, 2013)

1096-57-1927 **Selman Akbulut*** (akbulut@math.msu.edu), MSU, Dept. of Mathematics, E. Lansing, MI 48824. *Topology and duality in G_2 manifolds.* Preliminary report.

Previously with Salur we defined a notion of Mirror duality for a Calabi-Yau manifold pair inside of a G_2 manifold (M, φ), which is obtained by integrating pair of 6-plane fields which are dual to pair of associative/coassociative vector fields. Here we describe an approach to making the choice of these vector fields canonical. To accomplish this, we need to localize this process by restricting to neighborhoods special submanifolds (joint work with S. Salur). Also, I will describe cohomology ring calculatins of some bundles associated to (M, φ) in order to locate these special submanifolds (joint work with M. Kalafat). (Received September 16, 2013)

1096-57-1929 **Lenhard Ng** and **Dan Rutherford*** (drruther@uark.edu). *Satellites of Legendrian knots and representations of the Chekanov-Eliashberg algebra.*

The Chekanov-Eliashberg differential graded algebra (DGA) is an invariant of Legendrian knots in standard contact $\mathbb{R}^3$ that is a particular instance of Legendrian contact homology. There is a well-known correspondence between augmentations of the Chekanov-Eliashberg DGA and normal rulings of the front projection of L. We generalize this result to provide a necessary and sufficient condition for the existence of finite-dimensional representations of the DGA in terms of normal rulings of satellites of L. As a consequence, the existence of ungraded representations of any given dimension depends only on the Thurston-Bennequin number and underlying smooth knot type of L. (Received September 16, 2013)

1096-57-1976 **Gangotryi Sorcar***, sorcar@math.binghamton.edu. *Non-contractibility of the Teichmüller space of negatively curved metrics on certain non-locally symmetric negatively curved manifolds.* Preliminary report.

My results concern certain manifolds M that are not hyperbolic, but support Riemannian metrics of negative curvature (Gromov-Thurston branched covers), in other words manifolds that do not have the homotopy type of a locally symmetric space and prove that $\mathcal{T}^\infty(M)$ is non contractible by constructing a non trivial element in $\pi_1(\mathcal{T}^\infty(M))$, where $\mathcal{T}^\infty(M)$ denotes the Teichmüller space of all negatively curved Riemannian metrics on M, which is the quotient space of the space of all negatively curved Riemannian metrics on M modulo the space of all isotopies of M that are homotopic to the identity. (Received September 17, 2013)

1096-57-2029 **Heather A Dye*** (hadye@mckendree.edu), 701 College Rd, Lebanon, IL 62254, and **Micah Chrisman**. *The Three Loop Invariant.*

This talk is a report on the paper: The Three Loop Isotopy and Framed Isotopy Invariants of Virtual Knots. We introduce the three loop isotopy invariant, a virtual knot theory "analogue" of a well-known family of invariants for knots in thickened surfaces: the Grishanov-Vassiliev finite-type invariants of order two. We conclude with the properties of this invariant. (Received September 17, 2013)

1096-57-2061 **Carolyn Ann Otto*** (ottoa@uwec.edu), Eau Claire, WI 54703. *Successive Quotients of Filtrations of the String Link Concordance Group.* Preliminary report.

We establish results about the relationship between Milnor's invariants and several filtrations of the string link concordance group. Using this relationship we will investigate whether successive quotients of the filtrations are nontrivial. We will show relationships between the operation of Bing Doubling and Milnor's invariants and use this to generate examples in the successive quotients. Lastly, we will discuss possible methods and examples to discover whether these successive quotient groups are abelian groups. (Received September 17, 2013)

1096-57-2119 **Faramarz Vafaee*** (vafaeefa@msu.edu). *Heegaard Floer Homology and L-space Knots.*

Heegaard Floer theory consists of a set of invariants of three and four dimensional manifolds. One example of such invariants is the hat version of Heegaard Floer homology which is a Spin-c graded group. Lens spaces have the simplest Heegaard Floer homology, namely it is a rank one free group in each Spin-c structure. Any rational homology three sphere with this property is called an L-space. We pose a new family of knots(a subfamily of twisted torus knots) that admit some L-space surgeries. We also talk about different operations that one can perform on knots to obtain new knots admitting L-space surgeries. (Received September 17, 2013)

1096-57-2147 **Brian C Rushton*** (brian.rushton@temple.edu), 428 Wachmann Hall, Mathematics Department, Temple University, Philadelphia, PA 19122. *Quasi-isometry properties of subdivision rules.*

Finite subdivision rules are a new method for studying quasi-isometry properties. We show how to use subdivision rules to study several quasi-isometry properties of right-angled Artin groups and cubulated groups. (Received September 17, 2013)

1096-57-2277 **Barbara E Nimershiem*** (barbara.nimershiem@fandm.edu). *A Borromean Rings Quilt.* Preliminary report.

With much gratitude to William Thurston, we now know that almost all knots are hyperbolic (the exceptions being torus knots and satellite knots). The same can be said for non-splittable links. A hyperbolic knot or link is one whose complement in the 3-sphere has a complete hyperbolic structure. In his widely distributed lecture notes "The Geometry and Topology of 3-Manifolds," Thurston presented explicit geometric structures for several examples, including the Borromean rings. He did so by decomposing each complement into two polyhedra (with vertices removed) whose faces are identified. In this project, we construct a quilt that exemplifies Thurston's decomposition of the Borromean rings. The quilt forms the boundary between the two polyhedra, with each of the faces in a different color. The quilt also holds the rings themselves. (Received September 17, 2013)

1096-57-2294 **Arunima Ray*** (arunima.ray@rice.edu), Department of Mathematics, Rice University, MS-136, 6100 Main St., PO Box 1892, Houston, TX 77251-1892. *The fractal nature of the knot concordance group.*

Let P be a knot in a solid torus V. By tying V into any knot K, one obtains a function on the set of all knots; this is the classical satellite construction by the satellite operator P. Satellite operators descend to give well-defined functions on the knot concordance group. I will describe how a number of recent results show that a certain class of satellite operators give self-similarities of the knot concordance group at arbitrarily small scales. (Received September 17, 2013)

1096-57-2321 **Kate Petersen*** (petersen@math.fsu.edu). *Invariants of Character Varieties.*

The SL(2,C) character variety of a finite volume hyperbolic 3-manifold is a complex variety, which encodes information about the deformation of the hyperbolic structure of the manifold. I will discuss how some natural invariants of these sets are informed by the topology of the underlying manifold. (Received September 17, 2013)

1096-57-2404 **Allison L Gilmore*** (gilmore@math.ucla.edu). *Applications of knot Floer homology for singular knots.* Preliminary report.

This talk will survey knot Floer homology for singular knots, which was first introduced by Ozsváth, Szabó, and Stipsicz. We will introduce the theory, describe its relationship to an invariant of singular knots that appears in HOMFLY-PT homology, and discuss applications to the study of singular knots. (Received September 17, 2013)

1096-57-2484 **Hyunshik Shin*** (hshin@math.gatech.edu). *Pseudo-Anosov mapping classes with dilatation of algebraic degree $2g$.*

Thurston proved that for a closed surface of genus g, the algebraic degree of a pseudo-Anosov dilatation is bounded above by $6g-6$. However, little is known about which degrees occur. In this talk we will describe a construction of pseudo-Anosov homeomorphisms with degree equal to $2g$. (Received September 17, 2013)

1096-57-2509 **Tim D. Cochran** and **Eamonn Tweedy*** (eamonn@rice.edu). *Positive Links.*

Cochran and Gompf defined a notion of positivity for concordance classes of knots that simultaneously generalizes the classical notions of sliceness and positivity of knots. Their positivity essentially amounts to the knot being slice in a positive-definite simply-connected four manifold. We study an analogous property for links, and describe relationships with (generalized) Sato-Levine invariants, Milnor's linking invariants, and the Conway polynomial. (Received September 17, 2013)

1096-57-2520 **Raeyong Kim*** (kimr@math.ohio-state.edu), 231 West 18th Avenue, Columbus, OH 43210. *Generalizations of the Kan-Thurston Theorem.*

The Kan-Thurston theorem says that every complex X has the homology of some group G. In this talk, we study two generalizations of the Kan-Thurston Theorem : (1) If X is finite, G can be taken as a CAT(0) cubical group.

(2) Every finite complex is homotopy equivalent to classifying space for proper bundles of a virtual Poincaré duality group. (Received September 17, 2013)

1096-57-2619 **Sang-hyun Kim** and **Genevieve S Walsh*** (genevieve.walsh@gmail.com). *A Space of CAT(-1) structures.* Preliminary report.

We study a space of CAT(-1) structures associated to a right-angled Coxeter group. (Received September 17, 2013)

1096-57-2788 **Jason Thomson La Corte*** (jlacorte@uwm.edu). *Curvature-constrained path planning in nonpositively curved cube complexes.*

State complexes are nonpositively curved cube complexes that model the state spaces of certain dynamical systems, called reconfigurable systems, whose allowable transformations are given by a set of reversible local rules. Reconfigurable systems arise naturally in problems involving geometric group theory, metamorphic robotic systems, and traditional robotics. The problem of determining an optimal strategy for reconfiguring the system from a given initial state to a given goal state is equivalent to that of finding an optimal path between two points in the state complex. If we additionally require that allowable paths must have average curvature bounded above by a constant, and that they must have a prescribed initial direction, this problem becomes what is known as a Dubins problem with free terminal direction. We present some theoretical and computational results related to the Dubins problem with free terminal direction for certain classes of nonpositively curved cube complexes, including some square complexes which have for their 1-skeleta the Cayley graphs of Coxeter groups. (Received October 22, 2013)

58 ► Global analysis, analysis on manifolds

1096-58-125 **James Damon** and **Ellen Gasparovic*** (ellen.gasparovic@gmail.com). *Skeletal linking structures for multiple-region analysis.*

Consider a collection of distinct compact regions $\{\Omega_i\}$ in $\mathbb{R}^{n+1}$ with piecewise smooth boundaries, where the regions are allowed to intersect on their boundaries (in a generic way). For example, in 2D and 3D medical images, we encounter complexes of objects such as organs, glands, arteries, bones, etc. that may be modeled by such a collection. The goal of this talk is to introduce a skeletal linking structure for the configuration of regions which captures the regions' individual shapes as well as the "positional geometry" of the collection. This includes both the geometric properties of the individual regions as well as global geometry reflecting any relations between the regions. The linking structure builds on earlier work of Damon in which, for a single compact region with smooth boundary, he developed the notion of a "skeletal structure" as a generalization of the Blum medial axis. We introduce a number of volumetric invariants measuring features of a given collection, particularly the relative closeness and relative significance of the individual regions. These are then used to construct a "tiered graph," which provides a means of obtaining a hierarchy among the regions based on the orderings of significance and closeness. (Received August 01, 2013)

1096-58-272 **Xiangjin Xu*** (xxu@math.binghamton.edu), Department of Mathematical Sciences, Binghamton University-SUNY, 4400 Vestal Parkway East, Binghamton, NY 13902. *New Heat Kernel Estimates on Riemannian Manifolds with Negative Curvature.* Preliminary report.

Apply the new Li-Yau type Harnack estimates for the heat equations on manifolds with $Ric(M) \geq -K$, $K \geq 0$, which established by Junfang Li and the author [Advance in Mathematics 226(5) (2011), 4456-4491], we prove a new upper bound estimate for the heat kernel $H(x,y,t)$ of manifolds with $Ric(M) \geq -K$,

$$H(x,y,t) \leq A_K(t) V_x^{-1/2}(\delta(t)) V_y^{-1/2}(\delta(t)) \exp\left[-\frac{d^2(x,y)}{4t} + [1 + d^2(x,y)] B_K(t) \right],$$

where $A_K(t), B_K(t) : [0,\infty) \to [0,\infty)$ are bounded functions, and $\delta(t) \sim t$ as $t \to 0$ and $\delta(t) \sim 1$ as $t \to \infty$. While in the seminal work of Li-Yau [Acta Math. 156 (1986) 153-201.], the heat kernel upper bound estimates had δ-loss:

$$H(x,y,t) \leq C(\delta,n) V_x^{-1/2}(\sqrt{t}) V_y^{-1/2}(\sqrt{t}) \exp\left[-\frac{d^2(x,y)}{(4+\delta)t} + C_1 \delta K t \right],$$

where constant $C(\delta,n) \sim \exp\left[\frac{c_1}{\delta}\right]$ as $\delta \to 0$, due that there was non-sharp Harnack estimates on manifolds with negative curvature. Some new lower bound estimates of the heat kernel are also discussed. (Received August 26, 2013)

1096-58-394 **Luc Hillairet** (luc.hillairet@univ-orleans.fr), Université d'Orléans, UFR Sciences Bâtiment de mathématiques, Rue de Chartres, Orleans, IN B.P. 6759, and **Chris Judge*** (cjudge@indiana.edu), Indiana University, Department of mathematics, 831 E. Third St, BLOOMINGTON, IN 47401. *The Laplacian on a hyperbolic triangle has no positive Neumann eigenvalues.*

Consider the Laplacian acting on functions on a geodesic triangle in the upper half plane having normal derivative zero. We show that for the generic choice of triangle, this operator has no nonconstant L^2 eigenfunctions. (Received September 01, 2013)

1096-58-1529 **Laurent Younes*** (laurent.younes@jhu.edu), 3400 N Charles st, Johns Hopkins University, Clark Hall, Baltimore, MD 21218. *Riemannian Metrics on Spaces of Deformable Images and Measures: from Singular to Smooth.*

Based on the formalism of metamorphosis, it is possible to define Riemannian metrics on spaces of images or measures that are partially induced by the action of diffeomorphisms. We will review recent results applying this framework. The first one studies a metric defined on spaces of generalized functions, on which we make an explicit characterization of the geodesics that link discrete measures. The second one discusses a metric that is applicable to continuously differentiable images, within which the geodesic equation has solutions that are characterized by finite-dimensional dynamical systems. Using this property, we introduce an optimal control approach that optimizes solutions of such systems to compute geodesics between images.

(Joint work with Casey Richardson). (Received September 16, 2013)

60 ► Probability theory and stochastic processes

1096-60-117 **Takashi Owada** and **Gennady Samorodnitsky*** (gs18@cornell.edu). *Maxima of long memory stationary symmetric α-stable processes, and self-similar processes with stationary max-increments.*

We derive a functional limit theorem for the partial maxima process based on a long memory stationary α-stable process. The length of memory in the stable process is parametrized by a certain ergodic theoretical parameter in an integral representation of the process. The limiting process is no longer a classical extremal Fréchet process. It is a self-similar process with α-Fréchet marginals, and it has the property of stationary max-increments, which we introduce in this paper. The functional limit theorem is established in the space $D[0, \infty)$ equipped with the Skorohod M_1-topology; in certain special cases the topology can be strengthened to the Skorohod J_1-topology. (Received July 31, 2013)

1096-60-152 **Zhixin Yang*** (zhixin.yang@wayne.edu), 656 West Kirby FAB 1250, Detroit, MI 48201, **George Yin** (gyin@math.wayne.edu), 656 West Kirby FAB 1217, Detroit, MI 48201, and **Haibo Li** (lihb08@mails.tsinghua.edu.cn), Tsinghua University, Beijing, 100084, Peoples Rep of China. *Stability of Numerical Methods for Jump Diffusions and Markovian Switching Jump Diffusions.*

This work is devoted to stability analysis of numerical solutions to jump diffusions and jump diffusions with Markovian switching. Different from the existing treatments of Euler-Maurayama methods for solutions of stochastic differential equations, we use techniques from stochastic approximation. We analyze the almost sure exponential stability and exponential p-stability. The benchmark test model in numerical solutions, namely, one-dimensional linear scalar jump diffusion is examined first and easily verifiable conditions are presented. Then Markovian regime-switching jump diffusions are dealt with. Moreover, analysis on stability of numerical methods for linearizable and multi-dimensional jump diffusions is carried out. (Received August 09, 2013)

1096-60-158 **Leila Setayeshgar***, Department of Mathematical Sciences, Shelby Center for Science and Technology, Huntsville, AL 35899. *Large Deviations for a Stochastic Burgers' Equation.*

We prove the large deviations principle (LDP) for the law of the solutions to a stochastic Burgers' equation in the presence of an additive noise. Our proof is based on the weak convergence approach. (Received August 11, 2013)

1096-60-175 **Gregory F. Lawler*** (lawler@math.uchicago.edu), Department of Mathematics, University of Chicago, Chicago, IL. *The Minkowski content of the Schramm-Loewner evolution (SLE).*

The Schramm-Loewner evolution (SLE_κ) is a conformally invariant process in the plane arising as the scaling limit of critical models in statistical physics. For $0 < \kappa < 8$, the process gives curves of Hausdorff dimension

$d = 1 + (\kappa/8)$ but Hausdorff d-measure zero. We show that the d-dimensional Minkowski content of the curves exists, is nontrivial, and is the same as the natural d-dimensional parametrization. This is joint work with M. Rezaei. (Received August 13, 2013)

1096-60-179 **Hyunchul Park*** (hpark02@wm.edu), Hugh Jones Hall 132, Department of Mathematics, The College of William and Mary, Willimsburg, VA 23187, and **Renming Song**. *Trace estimates for relativistic stable processes.*

In 1966, Mark Kac asked if one could hear the shape of a drum. This means if one can figure out the geometry of the domain (drum) when one has perfect pitch so that he or she can hear all the fundamental tones (eigenvalues of the Laplacian or Brownian motions) of that drum. This turns out to be false. There exist isospectral but not isometric domains but one can still extract important geometric information such as area, perimeter, or even the Euler Characteristic from the eigenvalues of Dirichlet Laplacian of the domain.

A very natural question is what happens when we replace Brownian motions by other Levy processes. Relativisitic stable processes (RSP) are pure jump Levy processes whose jump rate is similar to stable processes for a small scale but have an exponential decay for a large scale. In a recent work with Song, we prove that one can identify area and perimeter of the domain from the information of eigenvalues of RSP. (Received September 11, 2013)

1096-60-206 **Joe P. Chen** and **Baris Evren Ugurcan*** (beu4@cornell.edu), Department of Mathematics, Cornell University, Ithaca, NY 14853. *Entropic repulsion of Gaussian free field on high-dimensional Sierpinski carpet graphs.*

Consider the free field on a fractal graph based on a high-dimensional Sierpinski carpet (*e.g.* Menger sponge), that is, a centered Gaussian field whose covariance is the Green's function for simple random walk on the graph. Moreover assume that a "hard wall" is imposed at height zero so that the field stays positive everywhere. We prove the leading-order asymptotics for the local sample mean of the free field above the hard wall on any transient Sierpinski carpet graph, thereby extending a result of Bolthausen, Deuschel, and Zeitouni for the free field on $\mathbb{Z}^d$, $d \geq 3$, to the fractal setting. (Received August 19, 2013)

1096-60-236 **Takao Namiki*** (nami@math.sci.hokudai.ac.jp), Kita 10 Nishi 8, Sapporo, Hokkaido 060-0810, Japan. *The baker's transformation and quantum walk.*

Though the research on quantum walk is developed in the recent decades, any counterpart of semi-classical approximation theory does not appear. First, to establish the notion of semi-classical approximation in quantum walk, we have to define classical random walk in the context of quantum walk and give a sequence of quantum walks which approximates the quantum walk equivalent to classical random walk.

In the presentation the author give a quantum walk driven by the baker's transformation and show that the quantum walk has the same statistical property as the classical random walk has. The baker's transformation is a typical example of uniformly hyperbolic dynamical system with invariant probability measure.

Moreover, properties of quantum walks driven by quantum baker's transformation are described. These quantum walks consist of a family of quantum walks which approximates classical random walk. (Received September 13, 2013)

1096-60-313 **Joshua Levy*** (joshua_levy@uml.edu), Dept. of Operations and Information Systems, University of Massachusetts Lowell, One University Ave., Lowell, MA 01854. *On a class of stable random processes that are self-similar but do not have stationary increments.* Preliminary report.

We begin to study some random processes having an integral representation with respect to a single α-stable random measure, $0 < \alpha \leq 2$. The integrand of a typical process in this class of α-stable processes is parametrized also by α and by positive numbers δ and H. When H lies in a certain bounded interval specified by prescribed functions of α and δ, the process is well-defined, and, in fact, is H-self-similar. Our aim is to determine those α and δ for which it has stationary increments. In the Gaussian case ($\alpha = 2$), for example, the increments are stationary if and only if $\delta = 1/2$. The process then must be fractional Brownian motion with H restricted to $(1/2, 1)$. When $\alpha = 1$, it fails to have stationary increments for all $\delta > 0$. What if $\alpha \in (0,1) \cup (1,2)$? This case is more delicate. (Received September 08, 2013)

1096-60-356 **Irina Holmes***, irina.c.holmes@gmail.com. *An Inversion Procedure for the Gaussian Radon Transform for Banach Spaces.*

The Gaussian Radon transform is an infinite-dimensional generalization of the classical Radon transform to real separable infinite-dimensional Banach spaces within the framework of abstract Wiener spaces. We prove a disintegration theorem leading to an expression of the Gaussian Radon transform as a conditional expectation and then prove an inversion procedure involving the Segal-Bargmann transform. (Received August 29, 2013)

1096-60-357 **Tobias Johnson*** (toby@math.washington.edu) and **Soumik Pal**. *Growing random regular graphs and the Gaussian Free Field.*

The spectral properties of Wigner matrices have been the subject of much recent study. The adjacency matrices of random regular graphs are something like Wigner matrices, and comparing the two tests the extent of universality. Alexei Borodin has recently found connections between the eigenvalues of sequences of minors of a Wigner matrix and the Gaussian Free Field. As an analogue, we investigate the eigenvalues of a sequence of growing random regular graphs, and we find similar connections. Along the way, we will paint a nice picture of the combinatorial behavior of our growing random regular graphs. This extends our work on fluctuations of linear eigenvalue statistics for random regular graphs.

This is joint work with Soumik Pal. (Received August 30, 2013)

1096-60-471 **Clement Boateng Ampadu*** (drampadu@hotmail.com), 31 Carrolton Road, Boston, MA 02132. *A Characterization of Continuous-time Quantum Walk with Phase Parameters.* Preliminary report.

In this talk we show how to construct the CTQRW from the DTQRW with phase parameters. Using the Hadamard gate as an example, we examine some basic properties of this CTQRW. (Received September 04, 2013)

1096-60-508 **Mihnea Stefan Andrei*** (mihnea.andrei@wpi.edu), 100 Institute Road, #2586, Worcester, MA 01609. *Dynamic models for the default risk of interbanking networks.* Preliminary report.

In 2008 a multitude of banks went bankrupt and had to be bailed out by the government. Although the rest is history, it is important to try to learn from the mistakes of the past. One way in which we could do this is by studying how contagion spreads through a banking system. As we will see, this question manages to bring together ideas from many fields in Mathematics: Combinatorics, Linear Algebra, Calculus, Statistics and Probabilities.

In this presentation we will try to characterize the spread of contagion by finding the expected time until the first bank defaults, the probabilities that each bank will default and some conditional probabilities. In order to do so, we will consider the banks to be the vertices of a graph. We draw an edge between 2 vertices if one of the banks has assets or liabilities with respect to the second one. This relationship is modeled using random walks. Next, this graphical representation can be transformed in a system of linear inequalities. Finally, by considering a multidimensional absorbed Markov chain, and by using PH random variables, we will arrive at a form of our initial problem which can be solved. Also, numerical methods will help us obtain some results and conclusions by implementing the ideas from the mathematical model into MATLAB. (Received September 05, 2013)

1096-60-528 **Davar Khoshnevisan*** (davar@math.utah.edu), Department of Mathematics, University of Utah, Salt Lake City, UT 84112-0090, **Jason Swanson** (jason@swansonsite.com), Department of Mathematics, University of Central Florida, Orlando, FL 32816-1364, **Yimin Xiao** (xiao@stt.msu.edu), Department of Statistics and Probability, Michigan State University, East Lansing, MI 48824-3416, and **Liang Zhang** (lzhang81@stt.msu.edu), Department of Statistics and Probability, Michigan State University, East Lansing, MI 48824-3416. *Some Very Rough Differential Equations.*

We prove that if $f:\mathbf{R}\to\mathbf{R}$ is Lipschitz continuous, then for every $H\in(0\,,1/4]$ there exists a probability space on which we can construct a fractional Brownian motion X with Hurst parameter H, together with a process Y that: (i) is Hölder-continuous with Hölder exponent γ for any $\gamma\in(0\,,H)$; and (ii) solves the differential equation $\mathrm{d}Y_t=f(Y_t)\,\mathrm{d}X_t$. More significantly, we describe the law of the stochastic process Y in terms of the solution to a non-linear stochastic partial differential equation. (Received September 05, 2013)

1096-60-537 **Elizabeth Skubak Wolf*** (skubak@math.wisc.edu). *Parameter Sensitivities for Discrete Stochastic Models in Continuous Time.*

In the analysis of parametrized models used in a wide range of fields including queueing theory, population processes, and chemical reaction networks, knowledge of parameter sensitivities is extremely useful. For example, these sensitivities, given by derivatives of system outputs with respect to model parameters, can significantly increase the efficiency of an optimization algorithm.

In the setting of cell biology, the advent of new technologies such as green fluorescent proteins have shown that stochastic models capture the dynamical behavior of the constituent molecules significantly better than deterministic models. Consequently, usage of these stochastic models has increased dramatically over the past decade. Determining the best ways to find or approximate the sensitivities of stochastic models is an interesting question, and a variety of methods have been developed in the last few years. In this talk I will discuss a relevant family of continuous time Markov chain models and highlight some of the sensitivity methods in this setting. I will also introduce new methods for these models which have little or no bias, as well as a low variance which leads directly to high efficiency. (Received September 05, 2013)

1096-60-561 **Sandra Cerrai*** (cerrai@math.umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742. *"On the quasi-potential for 2-D Navier-Stokes equations perturbed by space time white noise".*

We are dealing with the Navier-Stokes equation in a bounded regular domain D of $\mathbb{R}^2$, perturbed by an additive Gaussian noise $\partial w^{Q_\delta}/\partial t$, which is white in time and colored in space. We assume that the correlation radius of the noise gets smaller and smaller as $\delta \searrow 0$, so that the noise converges to the white noise in space and time. For every $\delta > 0$ we introduce the large deviation action functional $S^\delta_{0,T}$ and the corresponding quasi-potential U_δ and, by using arguments from relaxation and Γ-convergence we show that U_δ converges to $U = U_0$, in spite of the fact that the Navier-Stokes equation has no meaning in the space of square integrable functions, when perturbed by space-time white noise. Moreover, in the case of periodic boundary conditions the limiting functional U is explicitly computed.

Finally, we apply these results to estimate of the asymptotics of the expected exit time of the solution of the stochastic Navier-Stokes equation from a basin of attraction of an asymptotically stable point for the unperturbed system.

Joint work with Z. Brzezniak and M. Freidlin (Received September 06, 2013)

1096-60-614 **Marc Harper** (dash.fryer@gmail.com), Claremont, CA 91711, and **Dashiell Fryer*** (dashiell.fryer@pomona.edu), 610 North College Ave, Claremont, CA 91711. *Evolutionary Stability in Finite Populations.*

We extend the well-known Lyapunov stability results of evolutionary dynamics to both the Moran process and the Wright Fisher process with mutation. In particular, we show that local maxima of the stationary distribution of the Moran process can be characterized in three equivalent ways: (1) as evolutionarily stable states, suitably generalized; (2) states inducing equality in particular transition probabilities; and (3) as minima of an information-theoretic Lyapunov-like function that is a natural analog of relative entropy (a Lyapunov function for the replicator dynamic). Similar but more subtle results hold for the Wright-Fisher Process. If time allows, we will discuss an extension to evolutionary graph theory. (Received September 07, 2013)

1096-60-843 **Patricia Mehron Garmirian*** (patricia.garmirian@tufts.edu), 15 Bellevue Street, Medford, MA 02155. *A new, direct, and elementary proof of the Central Limit Theorem.*

We give a new, direct, and elementary proof of the general Central Limit Theorem (CLT). Two important stepping-stones are, first, a new, similarly direct and elementary proof of the CLT for Rademacher random variables defined on [0,1]. The second important stepping-stone is a new result for Bernstein polynomials of continuous functions. Bernstein polynomials are a fundamental object of mathematical analysis. It is well known that Bernstein polynomials of a continuous function on intervals $[0, b_n]$ when n tends to infinity return the value of the function for an appropriate rate of b_n, but uniform convergence is sacrificed. Nothing was known for the symmetric interval $[-b_n, b_n]$. We have proven that for these intervals the limit does not recover the function but rather its integral with respect to Gaussian measure. The extension to our direct proof of the of the general CLT involves a new and surprising connection between the CLT and the Haar basis on [0, 1]: the i.i.d. sequence of random variable is transformed to a sequence defined on [0,1] and the random variables in the transformed sequence are then expanded with respect to the Haar basis. (Received September 10, 2013)

1096-60-931 **Olusegun M Otunuga*** (otunuga@mail.usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, CMC 342, Tampa, FL 33620-5700, and **G S Ladde** (gladde@usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, CMC 342, Tampa, FL 33620-5700. *Multivariate Stochastic Dynamic Model of Energy Commodities Under External Interventions.* Preliminary report.

A multivariate stochastic model under external random interventions is 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. The U.S. Energy Information Administration data set (Natural Gas, Gasoline, Coal, and Electricity) is used to illustrate the scope of the developed model.

A correlation analysis is performed to study the short run relationship between these energy commodity spot prices while the developed stochastic model with continuous jump is used to analyze the long run relationship. (Received September 11, 2013)

1096-60-939 **Patrick Assonken*** (patrick13@mail.usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, CMC 342, Tampa, FL 33620-5700, and **G S Ladde** (gladde@usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, CMC 342, Tampa, FL 33620-5700. *Mathematical Modeling of Option Pricing Processes under Internal and External Stochastic Perturbations.* Preliminary report.

We develop a mathematical model for option pricing processes under both structural and external stochastic perturbations. The structural and external perturbations are described by hidden semi Markov and Levy jump processes, respectively. Introducing a few basic properties of the developed model, an infinitesimal generator and characteristic function are derived. An equivalent risk neutral measure is also exhibited. Furthermore, establishing an option pricing formula, simulation results are obtained. (Received September 11, 2013)

1096-60-958 **Michael Grabchak*** (mgrabcha@uncc.edu), UNC Charlotte, Department of Mathematics and Statistics, 9201 University City Blvd, Charlotte, NC 28223. *Properties of tempered stable distributions.*

Tempered stable distributions were introduced in Rosiński 2007 as models that look like infinite variance stable distributions in some central region, but they have lighter (i.e. tempered) tails. Such models have found applications in a variety of areas including mathematical finance, biostatistics, computer science, and physics. We extend this class to allow for more variety in the tails. While some cases no longer correspond to stable distributions they serve to make the class more flexible, and, in certain subclasses, they have been shown to provide a good fit to data. To characterize the possible tails we give detailed results about finiteness of various moments, and we give necessary and sufficient conditions for the tails to be regularly varying. This last part allows us to characterize the domain of attraction to which a particular tempered stable distribution belongs. We then describe the weak limits of sequences of tempered stable distributions, and we conclude by characterizing the long and short time behaviour of their associated Lévy processes. (Received September 11, 2013)

1096-60-959 **Yizao Wang*** (yizao.wang@uc.edu), 2815 Commons Way, Department of Mathematical Sciences, Cincinnati, OH 45221, and **Zakhar Kabluchko**. *Limit laws of maximal normalized set-indexed sum of heavy-tailed random variables.* Preliminary report.

We consider the maximum of a collection of normalized set-indexed sums of i.i.d. random variables with heavy tails. We establish limit laws of the maximum, when the sums are indexed by rectangular sets of $\mathbb{Z}^d$. This generalizes the work of Mikosch and Rackauskas (2010). If time permits, we talk about the problem with more general index sets. (Received September 11, 2013)

1096-60-996 **Yin Jun*** (jyin@math.wisc.edu), Select. *Isotropic Local Law and Deformed Random Matrix.*

In this talk, we introduce some recent work on distributions of eigenvalues and eigenvectors of the Wigner matrix (or covariance matrix) with finite perturbation. Especially the local laws about the outliers about these models. One of the main tools of these work is called local isotropic law. (Received September 12, 2013)

1096-60-1044 **Divine T Wanduku*** (wandukudivine@yahoo.com), Keiser University, 2400 Interstate Dr., Lakeland, FL 33805. *A Scale-Structured Network Stochastic Epidemic dynamic model with varying Incubation Period.* Preliminary report.

We present a stochastic SIR delayed epidemic dynamic model 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. We investigate the stochastic asymptotic stability of the disease free equilibrium and verify the impact on the emergence, propagation and resurgence of the disease. The presented results are demonstrated by numerical simulation results. (Received September 12, 2013)

1096-60-1074 **Farzad Sabzikar*** (sabzika2@stt.msu.edu), Department of Statistics and Probability, Michigan State University, East Lansing, MI 48824, and **Mark M Meerschaert** (mcubed@stt.msu.edu), Department of Statistics and Probability, Michigan State University, East Lansing, MI 48824. *Tempered fractional stable motion.*

This talk considers heavy tailed analogues to tempered fractional Brownian motion (TFBM), a process recently introduced by the authors [*Statist. Probab. Lett.* **83** (2013), 2269–2275]. TFBM modifies the power law kernel in the moving average representation of a fractional Brownian motion, adding an exponential tempering. The increments of TFBM exhibit semi-long range dependence, close to that of a fractional Gaussian noise at moderate lags, but ultimately short range dependent. Replacing the Gaussian random measure in the moving average or harmonizable representation of TFBM by a stable random measure, we obtain a linear tempered fractional stable motion, or a real harmonizable tempered fractional stable motion, respectively. Unlike the Gaussian case, linear tempered fractional stable motion and real harmonizable tempered fractional stable motion are two completely different processes. Existence, basic properties, sample path behavior, and dependence structure of both processes will be described. (Received September 12, 2013)

1096-60-1119 **Etsuo Segawa*** (e-segawa@m.tohoku.ac.jp), 980-8579, Japan. *Limit behaviors of quantum walks and spectral measure on the unit circle.*

We propose a method which connects a spectral measure of the unit circle to limit theorem of discrete-time quantum walk. We give examples that this method works well to show the weak convergence theorem in which specific stochastic properties of the quantum walks obtained by measurement of its quantum system; linear spreading and localization, for not only spatial homogeneous cases but also some spatial inhomogeneous cases. (Received September 13, 2013)

1096-60-1231 **Octavious Talbot*** (octavioustalbot@gmail.com), **Valerie Cheathon**, **Agustin Flores** and **Victor Suriel**. *Dynamics and Control of an Invasive Species: The Case of the Rasberry crazy ant Colonies.*

This project is motivated by the costs related with the documented risks of the introduction of non-native invasive species of plants, animals, or pathogens associated with travel and international trade. Such invasive species often have no natural enemies in their new regions. The spatiotemporal dynamics related to the invasion/spread of *Nylanderia fulva*, commonly known as the Rasberry crazy ant, are explored via the use of models that focus on the reproduction of ant colonies. A Cellular Automaton (CA) simulates the spatially explicit spread of ants on a grid. The impact of local spatial correlations on the dynamics of invasion is investigated numerically and analytically with the aid of a Mean Field (MF) model and a Pair Approximation (PA) model, the latter of which accounts for adjacent cell level effects. The PA model approach considers the limited mobility range of *N. fulva*, that is, the grid cell dynamics are not strongly influenced by non-adjacent cells. The model determines the rate of growth of colonies of *N. fulva* under distinct cell spatial architecture. Numerical results and qualitative conclusions on the spread and control of this invasive ant species are discussed. (Received September 13, 2013)

1096-60-1234 **Hyun Jae Yoo*** (yoohj@hknu.ac.kr), Dept. of Applied Mathematics, Hankyong National University, Anseong, Gyeonggido 456-749, South Korea. *Limit distributions of quantum walks and open quantum random walks.* Preliminary report.

We discuss the limit distributions of quantum random walks as well as open quantum random walks. Focusing on the generators of quantum walks (on lattice spaces), we can represent the moments of limit distribution by vacuum expectations of the powers of some operator. For open quantum random walks, we introduce a concept of dual processes and by which we can derive the limit distributions concretely for some models. (Received September 13, 2013)

1096-60-1236 **Jan S Reimann***, Department of Mathematics, McAllister Bldg, University Park, PA 16802. *Effective fractal dimensions for point processes.*

We introduce notions of effective fractal dimension for point processes. We study how they relate to generalized Renyi dimensions and investigate the consistency of estimators for these dimensions based on Kolmogorov complexity of point sets. We also study estimators based on compression algorithms instead of Kolmogorov complexity, and present some applications to seismological data. (Received September 13, 2013)

1096-60-1360 **Yusuke Ide*** (ide@kanagawa-u.ac.jp). *Fully inter-connected subgraph decomposition and continuous time quantum walks.*

In this talk, we introduce a concept of fully inter-connected subgraph decomposition of given graphs. Then we show the spectral analysis of graph Laplacian of decomposable graphs in this sense. After that we apply these results to continuous time quantum walks on specified decomposable graphs including complete graphs, star graphs, threshold graphs, etc. (Received September 15, 2013)

1096-60-1387 **Konstantinos Spiliopoulos*** (kspiliop@math.bu.edu), Department of Mathematics and Statistics, Boston University. *Systemic risk in large financial networks.*

The past several years have made clear the need to better understand the behavior of risk in large interconnected financial networks. Interconnections often make a system robust, but they can act as conduits for risk. In this talk, I will present recent results on modeling the dynamics of correlated default events in the financial market. An empirically motivated system of interacting point processes is introduced and we study how different types of risk, like contagion and exposure to systematic risk, compete and interact in large-scale systems. A law of large numbers for the loss from default is proven and used for approximating the distribution of the loss from default in large, potentially heterogeneous portfolios. Fluctuation analysis and conditional Gaussian approximations are used to improve the approximations. Then, large deviations theory allows us to capture the tail of the distribution and quantify large portfolio losses. Numerical results illustrate the accuracy of the approximations. The results give insights into how different sources of default correlation interact to generate typical and atypical portfolio losses. (Received September 15, 2013)

1096-60-1395 **Buffy Joy Lloyd** and **Omayra Ortega*** (omayra.ortega@asu.edu), Arizona State University, School of Mathematical and Natural Sciences, Phoenix, AZ. *An Age-Based Stochastic Model of HPV.*

Approximately 630 million people are infected with Human Papillomavirus (HPV) worldwide with six million new cases every year [4]. With over 200 different trypes identified, HPV is the most common sexually transmitted infection contributing to multiple adverse health outcomes including cervical cancer. In our study, we develop a stochastic model which describes the transmission of HPV infection in both men and women. We separate the women into the age groups of 12-19, 20-29, 30-65, 65+ and observe the rates of progression to disease, pre-cancerous cells, cancer and death in women. Our studies show that the 12-19 age group progresses to infection with HPV at the lowest rate, while the number of woman presenting with Low-Grade Squamous Intraepithelial Lesion (LSIL) peaks during the ages of 30-65 and women progressing to oncogenic HPV types peak at the age of 65+. (Received September 15, 2013)

1096-60-1465 **Igor Cialenco*** (igor@math.iit.edu), Dep. of Applied Math, IIT, 10 West 32nd Str, Bld E1, Room 208, Chicago, IL 60616, and **Tomasz R. Bielecki**, Dep. of Applied Math, IIT, 10 West 32nd Str, Bld E1, Room 208, Chicago, IL 60616. *On Bid-Ask Prices for Dividend Paying Securities: an acceptability index approach.*

We develop a framework for narrowing the theoretical spread between ask prices and bid prices of derivative securities in models of discrete time markets with transaction costs using dynamic coherent acceptability indices studied in Bielecki, Cialenco, and Zhang (2011). Aside from the use of acceptability indices as a tool, our approach is very much rooted in the literature studying good deal bounds as a vehicle to narrow the no-arbitrage interval. We first formulate and prove a no-good-deal version of the fundamental theorem of asset pricing (FTAP) using a family of dynamic coherent risk measures. The obtained results generalize to dynamic market model set-up the version of FTAP proved in Cherny and Madan (2010) in the static conic finance framework. We use the market model setup suitable for dividend-paying securities in markets with transaction costs. We discuss some applications of this theory to path dependent options and compute the good-deal ask and bid prices generated by dynamic gain-loss ratio (a particular dynamic acceptability index). Finally, we link the theory of stochastic backward difference equations to bid-ask prices in the dynamic conic finance framework. (Received September 15, 2013)

1096-60-1501 **Tomoyuki Ichiba*** (ichiba@pstat.ucsb.edu), South Hall 5607A Department of, Statistics and Applied Probability, University of California, Santa Barbara, CA 93106. *Interactions in the system of interbank lending.*

We consider diffusion models of the interbank lending system. The lending preferences from one bank to another characterize stability/instability of the system, in particular, multiple defaults of banks. These preferences can be seen as consequences of optimizations of each bank in the system. We examine boundary behaviors of the multiple defaults and propose financial health indicators. In order to understand effects of large-scale interactions among banks, we also discuss a process-level large deviation principle for the system and propagation of chaos result. (Received September 16, 2013)

1096-60-1524 **Iwao Sato*** (isato@oyama-ct.ac.jp), 771, Nakakuki, Oyama, 323-0806, **Norio Konno** (konno@ynu.ac.jp), Hodogaya, Yokohama, 240-8501, Japan, **Yusuke Higuchi** (higuchi@cas.showa-u.ac.jp), 4562, Kamiyoshida, Fujiyoshida, 403-0005, Japan, and **Etsuo Segawa** (e-segawa@m.tohoku.ac.jp), Sendai, 980-8579, Japan. *quantum walk and zeta function of a graph.*

Recently, it is turned out that discrete-time quantum walks on graphs are efficient for the graph isomorphism problem, and various approach are done in the graph isomorphism problem. Emms, E. R. Hancock, S. Severini and R. C. Wilson treated spectra of the Grover transition matrix of the Grover walk on a graph and its positive support etc, and showed that the positive support of the third power of the Grover transition matrix outperforms the graph spectra methods in distinguishing strongly regular graphs.

We determine the characteristic polynomials of them by using the determinant expressions of zeta function of a graph, and directly present spectra for them. Furthermore, we state the structure of the positive support of the cube of the Grover transition matrix etc. (Received September 16, 2013)

1096-60-1574 **Walid K Sharabati*** (wsharaba@purdue.edu) and **Mohamed El-Gebeily** (mgebeily@kfupm.edu.sa). *A Stochastic Approach of the Total Variation-Based Model for Image Reconstruction.*

The objective of image deblurring is to reduce the noise generated when the lens is out of focus, incoming light is bent, or object moves while shutter is open. In this work, we present a total variation model based on Tikhonov regularization with random coefficients to reconstruct the original image, the optimizer produces a nonlinear system of elliptic type integro-differential equations. To this end, we introduce a stochastic smoothing operator and develop a stochastic version of the cell-centered finite difference (CCFD) scheme defined on suitable finite dimensional deterministic and probability spaces. We incorporate spectral expansion techniques such as the KL expansion to eliminate the dependency on the random effect. The work also includes a discussion of the existence and uniqueness as well as convergence and stability of the approximated solution in the discretized subspaces. (Received September 16, 2013)

1096-60-1684 **Sean O'Rourke*** (sean.orourke@yale.edu). *Large random matrices with non-independent entries.*

The circular law asserts that if X_n is a $n \times n$ matrix with iid complex entries of mean zero and unit variance, then the empirical spectral distribution of $\frac{1}{\sqrt{n}}X_n$ converges almost surely to the uniform distribution on the unit disk in the complex plane as n tends to infinity. In this talk, I will consider what happens when the independence assumption on the entries is weakened. In some cases, the limiting distribution will no longer be the circular law. This is joint work with Hoi Nguyen and David Renfrew. (Received September 16, 2013)

1096-60-1686 **Roman Vershynin*** (romanv@umich.edu), Department of Mathematics, University of Michigan, 530 Church St, Ann Arbor, MI 48109, and **Mark Rudelson** (rudelson@umich.edu), Department of Mathematics, University of Michigan, 530 Church St, Ann Arbor, MI 48109. *Delocalization of eigenvectors of random matrices with independent entries.*

We develop a new, geometric approach to delocalization for random matrices. This approach yields that a random matrix with independent entries is completely delocalized. Suppose the entries of an $n \times n$ matrix G have zero means, variances uniformly bounded below, and a uniform tail decay of exponential type. Then with high probability all unit eigenvectors of G have all coordinates of magnitude $O(n^{-1/2})$, modulo logarithmic corrections. (Received September 16, 2013)

1096-60-1712 **Bertrand Duplantier*** (bertrand.duplantier@cea.fr), IPhT, Orme des Merisiers, CEA/Saclay, 91191 Gif-sur-Yvette Cedex, France. *Multifractality of Whole-Plane SLE.*

We study the average integral means spectrum of unbounded whole-plane SLE curves to prove the existence of a phase transition at a certain moment order, at which one goes from the bulk SLE multifractal spectrum to a new spectrum. The latter is related to radial SLE derivative exponents, and to non- standard, local tip exponents obtained from quantum gravity. The multifractal integral means spectrum for complex moment exponents is also determined.

Joint work with Chi Nguyen, Nga Nguyen and Michel Zinsmeister (Received September 16, 2013)

1096-60-1751 **Diane C. Holcomb*** (holcomb@math.wisc.edu) and **Benedek Valkó**. *Large deviations for point process limits of random matrices.*

The Gaussian Unitary ensemble (GUE) is one of the most studied Hermitian random matrix model. When appropriately rescaled the eigenvalues in the bulk of the spectrum converge to a translation invariant limiting point process called the Sine process. On large intervals one expects the Sine process to have a number of points that is roughly the length of the interval times a fixed constant (the density of the process). We solve the large deviation problem which asks about the asymptotic probability of seeing a different density in a large interval as the size of the interval tends to infinity. Our proof works for a one-parameter family of models called beta-ensembles which contain the Gaussian orthogonal, unitary and symplectic ensembles as special cases. (Received September 16, 2013)

1096-60-1837 **Antti Knowles*** (knowles@cims.nyu.edu). *The Altshuler-Shklovskii formulas for random band matrices.*

We consider the spectral statistics of large random band matrices on mesoscopic energy scales. We show that the variance and the two-point correlation function are governed by a universal power law behaviour that differs from the Wigner-Dyson-Mehta statistics. This law had been predicted in the physics literature by Altshuler and Shklovskii, and describes the eigenvalue density correlations in general metallic samples with weak disorder. Our result rigorously establishes the Altshuler–Shklovskii formulas for band matrices. In two dimensions, where the leading term vanishes owing to an arithmetic cancellation, we identify the first non-vanishing term and show that it differs substantially from the prediction of Kravtsov and Lerner. We also introduce a family of random band matrices that interpolates between real symmetric ($\beta = 1$) and complex Hermitian ($\beta = 2$) models, and track the transition for the mesoscopic density-density correlation. Finally, we prove that the two-point function completely describes the mesoscopic eigenvalue statistics by proving a central limit theorem for mesoscopic eigenvalue densities. (Received September 16, 2013)

1096-60-1892 **Manjunath Krishnapur**, **Brian Rider*** (brian.rider@temple.edu) and **Bálint Virág**. *Universality of the Stochastic Airy Operator.*

The Stochastic Airy Operator first arose as the continuum limit of certain ensembles of symmetric Gaussian random matrices in the vicinity of their spectral edge. We show that this picture persists for the general logarithmic gas on the line with uniformly convex polynomial potential. (Received September 16, 2013)

1096-60-1906 **Ted Theodosopoulos*** (ttheodosopoulos@saintannsny.org), 129 Pierrepont St, Brooklyn, NY 11201. *An algebraic framework for random satisfiability.* Preliminary report.

We introduce the 'truncator' map as a dynamical system on the space of configurations of a random Boolean network. We represent the resulting symbolic dynamics as a non-commutative ring and attempt to classify its periodic orbits. We construct a stochastic model on the space of endomorphisms of the resulting algebraic structures, and use it to probe the complexity of random satisfiability problems. (Received September 16, 2013)

1096-60-1918 **Kasper Larsen*** (kasperl@andrew.cmu.edu), Department of Mathematical Sciences, Wean Hall 7219, Pittsburgh, PA 15213, and **Jin Hyuk Choi**. *Taylor approximation of incomplete Radner equilibrium models.* Preliminary report.

In the setting of exponential investors and uncertainty governed by Brownian motions we first prove the existence of an incomplete equilibrium for a general class of models. We then introduce a tractable class of exponential-quadratic models and prove that the corresponding incomplete equilibrium is characterized by a coupled set of Riccati equations. Finally, we prove that these exponential-quadratic models can be used to approximate the incomplete models we studied in the first part. (Received September 16, 2013)

1096-60-1989 **Igor Rumanov*** (igor.rumanov@colorado.edu), Dept. of Applied Mathematics, 526 UCB, University of Colorado Boulder, Boulder, CO 80309. *Classical integrability, quantum integrability and Dyson beta ensembles of random matrices.* Preliminary report.

Probability distributions of eigenvalues of random matrix ensembles (RME)with symmetries are known to satisfy various integrable PDEs. Studying Dyson beta RME leads to new interesting relations between certain classical and quantum integrable systems. Some of their eigenvalue probability distributions satisfy Fokker-Planck (FP) equations with canonically quantized Painleve (a.k.a. (confluent) Heun) Hamiltonians. I show that any solution of a general FP type equation in one space (and one time) dimension can be considered as an eigenvector component of a matrix Lax pair. The example of largest eigenvalue distribution of large matrix size limit of a Wishart beta ensemble corresponds to quantum Painleve II in the above sense. A description of this distribution in terms of classical nonlinear integrable PDEs is made explicit and, for even values of parameter beta, is given in terms of system of ODEs involving beta/2 Calogero interacting particles in an additional time-dependent external potential. (Received September 17, 2013)

1096-60-2005 **Kevin Guo*** (klg2138@columbia.edu), New York, NY 10027, and **Tim Leung** (leung@ieor.columbia.edu). *Understanding the Risks of Commodity Exchange-Traded Funds.*

In this paper, we investigate the tracking errors of leveraged exchange traded funds (LETFs) based on commodity prices or indices. We first observe from empirical data the visible discrepancy in returns of these LETFs as compared to their reference indices. This leads us to define and analyze the tracking error time series associated with each LETF. We find that tracking errors can significantly deteriorate returns in the long run. Incorporating stochastic tracking errors into LETF price dynamics, we examine the effectiveness of a number of trading strategies. (Received September 17, 2013)

1096-60-2027 **Rama Shanker**, Asmara, and **Amanuel Habte Ghebretsadik*** (aman.habte1@gmail.com), Juja. *A bi-parameter New Quasi Lindley Probability Distribution.*

A new two parameters Quasi Lindley distribution is introduced. The moments, failure rate function, mean residual life function and stochastic orderings is discussed. The expressions for failure rate function, mean residual life function, and stochastic orderings of the new QLD shows its flexibility over Lindley distribution and exponential distribution and other related distributions. The maximum likelihood method and the methods of moments have been discussed for estimating its parameters. The distribution has been fitted to some data-sets to test its goodness of fit and it is found that to almost all these data-sets the new QLD provides closer fits than those by the Lindley distribution and other similar distributions (Received September 17, 2013)

1096-60-2040 **John P Nolan*** (jpnolan@american.edu). *Zolotarev type integral representations for multivariate stable laws.*

The lack of explicit formula for univariate and multivariate distribution functions and densities for stable distributions make them difficult to use in practice. We describe polar formulas for these quantities using a new family of special functions. Zolotarev type integrals are given and programs to compute these functions for low dimensions. (Received September 17, 2013)

1096-60-2120 **Agostino Capponi*** (acappon1@jhu.edu), Baltimore, MD 21210, and **Lijun Bo**, Xi'an, Peoples Rep of China. *Weak Convergence Analysis of Systemic Risk in Interbanking Networks.*

We develop a weak convergence analysis for a mean field model of interbanking lending activities. We model the monetary reserves of each bank as a system of jump diffusion processes, interacting through a separable lending preference function consisting of both an idiosyncratic and a common component, with the latter depending on the average monetary level of the system. We develop an explicit characterization of the limit measure valued process in terms of two deterministic functions reflecting the interbanking interaction, and recovered as the unique solution to a nonlinear system of equations. We use the limit process to construct law of large number approximation for popular banking stability measures, including average distance to default and joint probability of distress. We illustrate the predictive power and accuracy of our approximation framework via a detailed numerical analysis, showing that banking stability measures are highly sensitive to lending preference rates. The analytical tractability of our framework constitutes a useful tool for regulators to measure systemic risk and gauge its sensitivity to lending preferences, as well as volatility of monetary reserves. (Received September 17, 2013)

1096-60-2126 **Paul H Bezandry*** (pbezandry@howard.edu), 2441 6th Street, NW, Washington, DC 20059. *On the existence of almost automorphc solutions of nonlinear Volterra stochastic difference equation.*

In this talk, we introduce a concept of almost automorphy for random sequences. Using the Banach contraction principle, we establish the existence and uniqueness of an almost automorphic solution to some Volterra stochastic difference equation in a Banach space. Our main results extend some known ones in the sense of mean almost automorphy. As an application, almost automorphic solution to a concrete stochastic difference equation is analyzed to illustrate our abstract results. (Received September 17, 2013)

1096-60-2138 **Abhinandan Chowdhury*** (achowdhu@gettysburg.edu), Abhinandan Chowdhury, Gettysburg College, Campus Box 0402, Trailer 193, Gettysburg, PA 17325. *On the Application of Random-Point Approximation for Identification of the Effective Diffusivity Coefficient of Polydisperse Spherical Suspension.*

The so-called Random-Point Approximation (RPA) is applied to identifying the effective diffusivity of a polydisperse spherical suspension. The RPA is based on truncated Volterra-Wiener Expansion (VWE) with basis

function which is a random point function of perfect-disorder type. The VWE is applied consistently, and the equations for the kernels are derived. The contributions of the different kernels to the overall (effective) modulus are identified. An approximate model based on power-series expansion of the kernels with respect to the volume fraction c is developed. It is argued that the contribution of the pure binary interaction (two-sphere solution) is negligible for moderately concentrated suspensions. The issues connected with the application of the fourth-order kernel (one-sphere solution) are tackled, by evaluating some new kind of integrals. (Received September 17, 2013)

1096-60-2142 **Natasha Blitvic*** (nblitvic@indiana.edu). *Analysis in Non-tracial Non-commutative Probability Spaces.*

The setting for this talk is *non-tracial probability spaces*, that is, non commutative probability spaces of the form $(\mathcal{A}, \mathbb{E})$ where the expectation functional $\mathbb{E}$ does not satisfy $\mathbb{E}(a_1 a_2) = \mathbb{E}(a_2 a_1)$ for all pairs of non-commutative random variables $a_1, a_2 \in \mathcal{A}$. We will address the extent to which the lack of traciality impedes the probabilistic analysis of such spaces. We focus on the concrete examples of the q-Gaussian and (q,t)-Gaussian probability spaces (the former tracial, the latter non-tracial) and discuss explicit combinatorial constructions that will allow us to partially circumvent the non-traciality in the latter case. Examples of such constructions include the generalized Wick products, which will have applications to stochastic calculus and Segal-Bargmann analysis. (Received September 17, 2013)

1096-60-2181 **S. Sanyal*** (sanyal@marshall.edu). *Recent developments in Stochastic Dynamic Equations.*

Stochastic dynamic equations (SΔE) are the extension and unification of stochastic differential and difference equations. In this talk, I will present some recent developments, open problems, and its applications in mathematical finance. (Received September 17, 2013)

1096-60-2206 **Maytee Cruz-Aponte***, mcruzapo@asu.edu, Tempe, AZ. *Kolmogorov Equations Applied to a Metapopulation Epidemiological Model.* Preliminary report.

Mathematical modeling of infectious diseases can help public health officials to make decisions related to the mitigation of epidemic outbreaks. However, over or under estimations of the morbidity of any infectious disease can be problematic. Therefore, public health officials can always make use of better models to study the potential implication of their decisions and strategies prior to their implementation. The influence of different factors can change the course of an epidemic outbreak, by means of intervention or prevention. Considering the randomness of events can help study different factors that need to be taking into consideration for better policy making and interventions. By adding stochastic processes to meta-population models we can study this factors. In this work I present a continuous time stochastic modeling approach. We will consider the continuous-time Markov chain process using forward Kolmogorov equations. This stochastic modeling approach as well as the implemented simulations will be presented in a single city and two cities epidemic model using, as a base, our deterministic model constructed for the AH1N1 pandemic of 2009. (Received September 17, 2013)

1096-60-2253 **Valentina Staneva*** (vals@cis.jhu.edu) and **Laurent Younes**. *Parameter Estimation in Diffusion Processes on the Space of Shapes.*

In this work we model the deformations of 2D objects by formulating diffusion processes on the manifold of planar shapes. We introduce drift terms which are intrinsic to the shape by deriving the gradients of appropriate functions defined over the boundary of the shape. Given a sequence of observations from the path of the suggested stochastic differential equations, we propose a likelihood-ratio-based technique to estimate the missing parameters in the drift terms. We further show how to reduce the computational burden and improve the robustness of the estimators by constraining the motion of the shapes to a lower-dimensional submanifold equipped with a sub-Riemannian metric. (Received September 17, 2013)

1096-60-2260 **Horng-Tzer Yau*** (htyau@math.harvard.edu), Science Center 325, Cambridge, MA 02138. *Random Matrices and Dyson Brownian Motion.*

Wigner envisioned that the spectral statistics of large interacting quantum systems can be modeled by those of random matrices. A prominent example of this vision is the Wigner-Dyson-Mehta conjecture asserting that the spectral statistics of random matrices depend only on the symmetry classes but are independent of the distributions of matrix elements. Dyson proposed to study the dynamics of the eigenvalues of random matrices if all matrix elements evolved by Brownian motions. The induced evolution of these eigenvalues is called Dyson Brownian motion. Dyson observed that this dynamics approaches equilibrium in two time scales: a slow relaxation for global modes and a fast one for local fluctuations. We will show that this fundamental observation can indeed be made rigorous and it is in fact the cornerstone of the recent solution of Wigner-Dyson-Mehta conjecture. Related progress in random matrix theory will also be discussed. (Received September 17, 2013)

1096-60-2273 **Ryan M Thurman*** (`rthurman@mail.usf.edu`), 6203 Markstown Dr, Apt D, Tampa, FL 33617, and **G S Ladde** (`gladde@usf.edu`), Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, CMC 342, Tampa, FL 33620-5700. *Logistic Comparison Growth Model: Parametric Domain Decomposition and Statistical Analysis.* Preliminary report.

Using the comparison method and the idea of a minimal class of functions, a logistic growth model—with applications in epidemiology, psychology, and many other scientific areas—is derived. Parameter estimation using the existing methods and the exploration of future methods that utilize the analytic properties of the model are discussed. Parameter bounds are established using bounds on the model expectation function and length of time to the proximity of the saturation level. Lastly, the model is applied to HIV prevalence, as a function of time. (Received September 17, 2013)

1096-60-2296 **Adina Oprisan*** (`aoprisan@barry.edu`), Depart. of Mathematics and Computer Sciences, Barry University, Miami Shores, FL 33161. *On an almost sure functional central limit theorem for Semi-Markov processes.*

In this talk I discuss the long-run behavior of complex discrete-event stochastic systems. The underlying stochastic process of a discrete-event system is a semi-Markov process that evolves over continuous time according to a discrete-time Markov chain. In applications a reward structure is often associated with the underlying process. A general model for the reward earned over the interval $[0, t]$ is

$$R(t) = \sum_{n=1}^{N(t)} r(S_{n-1}, S_n) + \int_0^t f(X(u))du$$

where $r(s, s')$ is the lump-sum reward whenever the system makes a transition from the state s to the state s' and $f(s)$ is a continuous reward rate. I show that the functional central limit theorem of the reward process (P. Glynn and P. Haas, 2004) admits an almost sure version based on empirical measures with logarithmic average associated with the corresponding scaled process and further prove a Donsker-Varadhan type of large deviation result. (Received September 17, 2013)

1096-60-2331 **U. Tuncay Alparslan*** (`tuncay.alparslan@american.edu`), 4400 Massachusetts Avenue, NW, Washington, DC 20016. *Ruin with Single and Multiple Streams of Stable Claims.*

We study the tail behavior of the supremum of a random walk with stationary ergodic stable increments and a nonlinear negative drift. In actuarial mathematics, this gives the ruin probability. Our main result asymptotically relates this quantity to a functional based on the integral representation of the increment process in the context of a large class of negative drifts. This result is then applied to two different examples to demonstrate how the magnitude of the exceedance probability of a high threshold for such random walks can vary. Extensions to multivariate ruin are discussed. (Received September 17, 2013)

1096-60-2553 **Sajjad Z. Meymand*** (`sajjadzm@vt.edu`), Mechanical Engineering Department, Virginia Tech, Blacksburg, VA 24060, and **Mittu Pannala** and **John B. Ferris**. *Predicting the Outcome of a Soccer Championship.*

A model for predicting the outcome of a soccer tournament is proposed based on the FIFA ratings and also the attacking/defensive strengths introduced from past results for each team. To this end, the probability of goals scored is estimated as a Poisson distribution. The mean of this Poisson distribution will vary according to the quality of the team. Two Poisson log-linear models are developed based on past FIFA official rating values and attacking and defensive strengths of teams. An important parameter considered in this paper is the weighting factor, h, which accounts for the relative importance of the FIFA ratings or the attacking/defensive strengths. The weighting factor played an interesting role in determining the goals scored. FIFA world cup 2010 is simulated as a case study. Better predictions are made when both the factors are taken into consideration. Considering the attacking/defensive strength in addition to the FIFA ratings would bring a flexibility of updating the strengths after each stage of the tournament which would better predict the champion. The method introduced here can be generalized to consider other factors like quality-of-coaching/coach, quality of individual players etc., and hence improving the predictability. (Received September 17, 2013)

1096-60-2654 **Seonja Kim*** (sjkim@njit.edu), New Jersey Institute of Technology, University Heights, Department of Mathematical Sciences, Newark, NJ 07102-1982, and **Maxim J. Goldberg** (mgoldber@ramapo.edu), Ramapo College of New Jersey, 505 Ramapo Valley Rd., Mahwah, NJ 07430. *Using l_1 to define a natural diffusion distance.* Preliminary report.

Diffusion approaches have been used in the last several years to describe and analyze the underlying geometry of a given data set. One starts by constructing a diffusion matrix—a Markov matrix modeling discretized heat flow (or possibly a nearest neighbor random walk) on the data. The eigenvalues and eigenvectors of this matrix (or its symmetric version) can be used to build an isometric embedding of the data points. This isometry is expressed in the l_2 metric, and often leads to l_2 being used in defining a related diffusion distance. However, l_2 does not seem very natural for this situation since the rows of the diffusion matrix are probability densities which are normalized in l_1. Another indication that l_1 is more desirable than l_2 arises from considering the continuous case situation of heat flow in n-dimensional Euclidean space. An L_2 analog gives rise to Euclidean distance with time scale dependent on the dimension n, while an L_1 analog involves Euclidean distance with time scale independent of n, which seems intrinsically more desirable.

In this talk we present our investigation of defining and exploring the properties of l_1-based diffusion distances. (Received September 17, 2013)

1096-60-2655 **Stephanie Taylor***, sltayl10@asu.edu, and **Bruno Welfert**. *Slow Passage Problem via Markov and Itô Processes.*

This presentation considers a spring-mass system with periodic harmonic forcing. The frequency of the forcing evolves stochastically. We consider the effect of the stochasticity in a slow linear ramp of the frequency on the delay or early occurrence of the resonance in the system. We also consider two implementations of the stochastic process using either a Markov or Itô process. This study examines the connection between Itô and Markov formulation and analyzes the differences in both the implementation and results of the different types of noises. (Received September 17, 2013)

1096-60-2718 **Jeff Hamrick*** (jhamrick@usfca.edu), University of San Francisco, School of Management, 2130 Fulton Street, San Francisco, CA 94117. *Calibration of Stable Distributions to Option Prices.* Preliminary report.

Equity call and put option prices clearly encode the market's opinion about the distribution of future returns on the underlying. In a seminal paper from earlier this last decade, Jackwerth and Rubinstein use a nonparametric technique to obtain an estimate of this probability distribution. Unfortunately, their technique generates return distributions that are bounded from above and below. This feature is not especially realistic. Stock returns, after all, are well-known to be heavy-tailed and exhibit negative skewness.

We adopt the perspective that stock returns have a stable distribution. We use the associated risk-neutral probability distribution required to price equity call and put options in an arbitrage-free way, and develop a program of optimization for obtaining parameters that govern the stable distribution.

We find that, when compared to our technique, traditional numerical maximum likelihood estimation techniques understate the tail heaviness and left-skewness of the return distributions implied by equity call and put option prices. As a result, derivative traders and portfolio managers concerned about fat tails and left-skewed returns may prefer our technique to the more traditional approach. (Received September 18, 2013)

1096-60-2721 **Andrew Papanicolaou*** (alpapani@maths.usyd.edu.au), Carslaw Building, F07, University of Sydney, NSW 2006, Australia. *Mean-Field Games of Inhomogeneous Populations in Financial Markets.*

We consider a financial market with multiple agents. The literature has various results on the mean-field behavior of models with a large number of rational agents, both for the cases of homogenous and inhomogeneous populations. There are also results on markets with major agents whose affect is present even in the large population dynamics. In this work we explore some of the more recent results and finance applications. (Received September 18, 2013)

1096-60-2768 **Mauro Maggioni*** (mauro.maggioni@duke.edu). *Estimation of probability measures in high dimensions, with optimal transport and fast algorithms*

We introduce a novel class of algorithms for the estimation of probability measures in high-dimensional spaces, given a finite number of samples. We are particularly interested in the case when the probability measure is concentrated near a low-dimensional set. These algorithms are based on geometric multiscale decompositions of probability measures, and we prove that with high probability, given a sufficiently large but finite number of samples, the algorithm returns a probability measure which is close, in Wasserstein-Kantorovich distance, to the target probability measure. We discuss applications to modeling high-dimensional noisy data sets, and anomaly detection in time-varying data. (Received October 02, 2013)

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1096-62-224 **Bobson Wong*** (bwong3@schools.nyc.gov), Bayside High School, 32-24 Corporal Kennedy St., Bayside, NY 11361. *The Meaning of the Mean.* Preliminary report.

Although many people are familiar with the arithmetic mean as a measure of central tendency, few understand how it connects to the real world or even where the formula comes from. To them, adding a data set's values and dividing by the number of values is simply an arbitrary calculation with little basis in reality. Based on the author's experience teaching statistics to high school students, this session will explore ways that students can understand the mean through simple physical demonstrations and other examples in probability and statistics. The session will contain many approaches for teaching the mean and the related concept of expected value (a key part of the Common Core Standards' probability section) to K-12 students. It will show how the mean is applied in sports (quarterback rankings), education (weighted grades),test-taking (guessing on a multiple-choice test), physics (centroid), and other real-world topics. The session will also discuss why students struggle with basic statistical concepts and how students can overcome these obstacles. (Received August 21, 2013)

1096-62-239 **Marylesa Howard*** (howardmm@nv.doe.gov), **Michael Fowler** and **Aaron Luttman**. *Bayesian Abel Inversion with MCMC Sampling in Quantitative X-ray Radiography.*

A common image formation process in X-ray radiography is to have a pulsed power source that emits X-rays which are, in turn, absorbed by a scintillator. The scintillator visibly fluoresces in response to the absorbed photons and a CCD camera images the visible light emitted. In this framework, given a radially symmetric object, the intensity image can be interpreted as an Abel transform of the function representing density along the lines of the sight in the scene. We present a Markov Chain Monte Carlo approach for solving the Abel inversion, resulting in a posterior distribution from which the Abel-inverted image can be sampled. We take the image solution to be the mean of the posterior distribution and use the variance of the posterior as a measure of the uncertainty in the reconstruction. Furthermore, we determine uncertainty in the prior precision matrix as well. Results on both 1D and 2D, synthetic and real images from a high energy X-ray source will be presented.

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1096-62-372 **Zheng Wei*** (weizheng@nmsu.edu), New Mexico State University, Las Cruces, NM 88001, **Tonghui Wang**, New Mexico State University, Las Cruces, NM 88001, and **Wararit Panichkitkosolkul**, Thammasat University, Thailand. *Dependence and Association Concepts through Copulas.*

Abstract: In this paper, dependence concepts such as affiliation, left-tail decreasing, right-tail increasing, positively regression dependent, and positively quadrant dependent are studied in terms of copulas. Relationships among these dependent concepts are obtained. An affiliation is a notion of dependence between two positively dependent random variables and some measures of it are provided. It has been shown that the affiliation property is preserved using bilinear extensions of subcopula. As an application, the affiliation property of skew-normal copula is investigated. For illustration of dependent concepts and their relationships, several examples are given. (Received August 30, 2013)

1096-62-808 **Julie M Clark*** (jclark@hollins.edu), 8003 Fishburn Drive, Hollins University, Roanoke, VA 24020. *Investigating Statistical Concepts, Applications and Methods using Minitab.*

This presentation will describe the use of Minitab in an introductory (mathematical intensive major-based) statistics course that is part of a randomization-based curriculum using a text written by Chance & Rossman. The approach emphasizes the entire process of statistical investigations, from design of data collection through statistical inference, throughout the course. The inference techniques are based on randomness introduced in data collection, specifically randomization and permutation tests, rather than on normal-based probability models. The goal is to lead students to develop a deeper understanding of fundamental concepts of statistical inference and of the process through which statisticians investigate research questions by collecting, analyzing, and drawing conclusions from data. Real data from genuine studies motivates all of the activities, which make extensive use of technology, in this case, Minitab. (Received September 10, 2013)

1096-62-867 **Grant B Weller*** (grantw@cmu.edu), Department of Statistics, 132 Baker Hall, Pittsburgh, PA 15213, and **Daniel Cooley** (cooleyd@stat.colostate.edu). *A Sum Characterization of Hidden Regular Variation in Multivariate Extremes.*

Many statistical methods for multivariate extremes rely on an underlying multivariate regularly varying probability distribution. Under this framework, dependence in the tail of the distribution is described by a limiting measure, which in some cases is degenerate on joint tail regions despite possible dependence in such regions at finite levels. Hidden regular variation, a higher-order tail decay on these regions, offers a refinement of the regular variation framework. We develop a representation of random vectors possessing hidden regular variation as the sum of independent regular varying components. The representation is shown to be asymptotically valid via a multivariate tail equivalence result. We develop a likelihood-based estimation procedure from this representation via a Monte Carlo expectation-maximization algorithm which has been modified for tail estimation. The methodology is employed in an air pollution monitoring application. (Received September 10, 2013)

1096-62-870 **Mitra Lal Devkota*** (mitra.devkota@sdstate.edu), Department of Mathematics and Statistics, South Dakota State University, Harding Hall, Brookings, SD 57007, **Gary D Hatfield**, Department of Mathematics and Statistics, South Dakota State University, Harding Hall, Brookings, SD 57007, and **Rajesh Chintala**, South Dakota State University, Department of Plant Science, Brookings, SD 57006. *Effect of Sample Size on the Performance of Ordinary Least Squares and Geographically Weighted Regression.* Preliminary report.

A recently developed spatial analytical tool, Geographically Weighted Regression (GWR) was used to deal with spatial nonstationarity in modeling the crop residue yield potential for North Central region of the USA. Average of daily mean temperature and total precipitation of crop growing season were the explanatory variables. In this study, Moran's I and Geary's C were used to test the spatial autocorrelation of OLS and GWR residuals. The explanatory power of the models was assessed by approximate likelihood ratio test. Furthermore, the test of spatial heterogeneity of the GWR parameters was conducted by using data sets with small and large samples. Test of spatial autocorrelation of residuals revealed that the OLS residuals had higher degrees of spatial autocorrelation than the GWR residuals indicating that GWR mitigated the spatial autocorrelation of residuals. Results of the approximate likelihood ratio test showed that GWR models performed better than the OLS models suggesting that the OLS relationship was not constant across the space of interest. More importantly, it was demonstrated that the data set would have to be large enough for the individual parameters of GWR models to be spatially heterogeneous. (Received September 10, 2013)

1096-62-1051 **Mami T Wentworth*** (mtonoe@ncsu.edu), North Carolina State University, Department of Mathematics, Campus Box 8201, Raleigh, NC 27695, and **Ralph C Smith** (rsmith@ncsu.edu). *Verification techniques for Bayesian model calibration.* Preliminary report.

We discuss techniques to verify the accuracy of parameter or input densities constructed using Bayesian inference. The posterior distribution can be computed using the prior distribution, likelihood and possibly high-dimensional integration. We first employ a direct method to compute the posterior using the formula directly via a numerical quadrature. We then compare the direct method to two adaptive methods, Delayed Rejection Adaptive Metropolis (DRAM) and Differential Evolution Adaptive Metropolis (DREAM). These methods employ a MCMC algorithm and efficiently estimate model parameters without involving high-dimensional integration. We use a steady-state heat model as an example to demonstrate how these methods construct densities and compare their accuracy. (Received September 14, 2013)

1096-62-1122 **Jeff Randell Knisley*** (knisleyj@etsu.edu), Box 70663, Dept. of Math/Stat, East Tennessee State University, Johnson City, TN 37614-0663. *Consensus Spectral Techniques and Machine Learning.*

There is a long and fruitful history in the use of spectral methods in proteomics and genomics, especially when such techniques have been used to produce consensus spectra and consensus models for homological families of residue chains. Typically, these methods have focused on either periodicity – such as the fact that coding regions in DNA have 3-base periodicity – or on the use of biophysical measures such as the Electron-Ion Interaction Potential (EIIP) and its relationship to hot spots in amino acid chains. However, these methods can be extended into a more general framework, one that can be interpreted in terms of artificial neural networks and that subsequently can be applied both to complex networks and the data mining of large, complex data. Moreover, a major component of this approach is a resampling technique that allows not only the construction of a consensus model, but also a means of estimating confidence intervals from the resulting empirical distribution. We begin by establishing this framework, after which we move to its implementation, focusing on the machine learning toolkit scikit learn. The algorithms and examples in the talk will be freely available as an IPython Notebook shared via the data analysis framework Wakari. (Received September 13, 2013)

1096-62-1608 **Monica Christine Jackson*** (monica@american.edu), **Adria Trotman**, **Melissa Stephens** and **Kimberly F Sellers**. *The Effect of Latency Variables on Repeated Measures Inference Applied to the Measurement of Risk-taking as a function of Psychopathy.*

In numerous psychology studies, subjects are asked to perform some task a number of times, T. The effect of the choice of T on the associated inference, however, is usually not assessed. We investigate the appropriate choice of T empirically by using data collected in a study on the relationship between psychopathy and risk-taking in 90 inner city drug users enrolled in a residential treatment program. We show that, when studying this relationship, the latency variable usually discarded from the analysis behaves exponentially allowing a natural division of the study period $1,\dots,T$ into two distinct subperiods. These subperiods yield significantly different results – in the early period only (which we call "reactive"), subjects with high psychopathy scores exhibit lower sensitivity to reward and punishment in our risk taking experiment. The later period (which we call "stable") shows no relationship between sensitivity to reward and punishment and psychopathic tendencies. (Received September 16, 2013)

1096-62-1653 **Benjamin A Shaby*** (bshaby@psu.edu) and **Brian J Reich** (bjreich@ncsu.edu). *Fully Bayesian inference for spatial extremes using hierarchical extreme value processes.*

We describe a an approach for constructing spatial max-stable models through a hierarchical representation that conditions on latent positive stable random variables. This class of models approximates and extends known spatial max-stable processes and, critically, is amenable to fully Bayesian inference through MCMC. Moreover, this hierarchical framework provides a foundation that can be extended in a fairly straightforward way to produce, for example, multivariate extreme value fields, or fields with more flexible spatial dependence structures. (Received September 16, 2013)

1096-62-1812 **Margaret N, Barth** (mbarth@calbaptist.edu), **Melissa Wiggington** and **Benjamin David Knisley*** (bknisleystatistics@gmail.com), 8432 Magnolia Ave, PMB 140, Riverside, CA 92504, and **Hanna Stipeak**, **Grace Crosby** and **Linn Carothers** (lcarothers@calbaptist.edu). *Anthropometric indicators of obesity in Native American Adolescents and Exploratory Data Analysis.*

The baseline anthropometric indicators on Native American adolescents were obtained. This study represents a cross-sectional, epidemiological population (N=183) of institutionally-based, urban resident Native Americans adolescents (ages 14-18) from a wide variety of tribal groupings.

Using data from The Center for Disease Control and The National Health and Nutrition Examination Surveys (NHANES III), comparisons were made to baseline anthropometric measures of height, weight, waist, hip, tricep, and calf skin-folds for both genders.

While the majority of male and female adolescents fell well within national parameters of normal growth and weight for age, obesity is a concern for both genders of these relatively healthy Native American adolescents. The assessment of health risk by body-mass indices, appropriateness in use for intervention and correlation with anthropometric measures may prove of significant interest, especially for clinical monitoring of ongoing health concerns for Native American adolescents.

Key words: Native American Adolescents, Obesity, Body Mass Index (BMI) (Received September 16, 2013)

1096-62-2066 **Mark M. Meerschaert**, Michigan State University, East Lansing, MI, **Hans-Peter Scheffler**, University of Siegen, Siegen, Germany, and **Stilian A. Stoev*** (sstoev@umich.edu), University of Michigan, Department of Statistics, 439 W. Hall, 1085 S. University Rd, Ann Arbor, MI 48109. *Extreme value theory with operator norming.*

We propose a new approach to multivariate extremes using operator norming. We briefly introduce some limit theorems for the angular extremes of multivariate heavy tailed data. Operator norming allows us to handle in a unified way distributions with different tail exponents in different directions. We then present a method for simulating the limit process and a parametric bootstrap type procedure for testing for the need of operator norming. The statistical test is illustrated over simulated and real data sets. (Received September 17, 2013)

1096-62-2108 **Ionut Florescu*** (ifloresc@stevens.edu), 1 Castle Point on the Hudson, Babbio Center 544, Hoboken, NJ 07030, and **Khaldoun Khashanah** and **Steve Yang**. *The state of High Frequency Trading from the perspective of an institutional investor.* Preliminary report.

In this presentation we will discuss the state of High Frequency trading from the perspective of an interested investor. We will discuss the statistics of a recent survey on the subject and we will attempt to give a definition to characterize a High Frequency trader. We will also analyze potential regulatory responses to the phenomenon. (Received September 17, 2013)

1096-62-2288 **Katherine M. Kinnaird*** (katherine.m.kinnaird.gr@dartmouth.edu), 6188 Kemeny Hall, 27 N. Main Street, Hanover, NH 03755. *Hierarchical Representation for High-Dimensional Data in Music Structure Tasks.* Preliminary report.

We propose a novel hierarchical representation for high-dimensional, time-sequenced data that encodes relevant size-appropriate information at several scales. We apply this representation to Music Information Retrieval (MIR) structure tasks, by building a signature for each digital score in our data set of Chopin Mazurka scores. This signature captures repeated structure at several scales and is naturally hierarchical. Given a particular MIR structure task, such as locating a chorus or motif of a given musical song or score, we restrict our analysis to found repetitions of a task-appropriate range of scales. Including repetitive structure of all possible scales allows our representation to be applicable to a more diverse set of MIR structure tasks than other structure representations in the literature that focus only on the coarsest level of structure. (Received September 17, 2013)

1096-62-2312 **Nguyet T Nguyen*** (nnguyen@math.fsu.edu), 165 Crenshaw #12, Tallahassee, FL 32310. *Hidden Markov Model for High Frequency Data.*

Hidden Markov Models (HMM) are used for both single and multiple observation time series data. In particular, HMMs are used to predict the hidden regimes of these observations. Therefore they are widely applicable in many different areas such as speech recognition systems, computational molecular biology, and financial economic predictions.

We use HMMs for multiple observation data and for single observation data to predict the economic regimes and stock prices. We find that the HMMs for multiple observation data dominate the HMMs for single observation data in the prediction of daily stock prices and of monthly economic regimes. Our new application of HMMs for high frequency data gives impressive results. HMMs can predict a stock bid price in the next second with a relative error less than 0.001. (Received September 17, 2013)

1096-62-2357 **Eric Ruggieri*** (eruggier@holycross.edu), College of the Holy Cross, Dept. of Mathematics and Computer Science, Worcester, MA 01610. *A Sequential Approach to Detecting Change Points.* Preliminary report.

Imagine trying to model a data set where the model is suspected to change from one section of the data to the next. The difference could be as simple as a change in the mean, slope, or frequency of a signal. Each time the model is altered is called a 'change point', and identification of these change points is not always a trivial task. A time series containing N data points has approximately N^k distinct placements of k change points, rendering brute force enumeration futile as the length of the time series increases. Moreover, how certain are we that any one placement of change points is superior to the rest? In this talk, I'll introduce a sequential Bayesian change point algorithm which provides uncertainty estimates both in the number and location of change points through an efficient probabilistic solution to the multiple change point problem. The algorithm is able to quickly update itself with the arrival of each new observation and can accurately predict where in the data set a change point has occurred. (Received September 17, 2013)

1096-62-2393 **Mouchumi Bhattacharyya*** (mbhattac@pacific.edu), 3601 Pacific Avenue, University of the Pacific, Stockton, CA 95211. *To pool or not to pool.*

When it comes to testing hypotheses regarding two population means, the most commonly used test is the two-sample t-test. There are two versions of this test, one is used when the variances of the two populations are equal (the pooled test) and the other one is used when the variances of the two populations are unequal (the unpooled test). The pooled test seems to have fallen into some disfavor because of its 'claimed' sensitivity to departures from the assumptions of equal population variances. Through a simulation study, we demonstrate that although both the pooled and the unpooled test under-perform at times in their allocated settings, the overall performance of the pooled t-test is significantly superior to that of the unpooled t-test. (Received September 17, 2013)

1096-62-2468 **Elias Bareinboim*** (eb@cs.ucla.edu), Computer Science Department, Los Angeles, CA 90095-1596, and **Judea Pearl** (judea@cs.ucla.edu), Computer Science Department, Los Angeles, CA 90095-1596. *Mathematical Challenges in Causal Inference with Emphasis on Transportability and External Validity.*

Recent advances in graphical models and the calculus of actions have given rise to mathematical problems that are not easily formalized, let alone solved in the conventional language of probability and statistics. We exemplify this challenge through one such problem – transportability – which aims to determine when it is feasible to generalize experimental findings from one or several environments to another, potentially different from the rest. This problem is at the heart of every scientific investigation since, invariably, experiments performed in one environment (or population) are intended to be used elsewhere, where conditions may differ considerably. Using a graphical representation of differences and commonalities among two or more environments, we provide a formal characterization and complete algorithmic solution to the problem of whether a specific causal effect is transportable across environments and, if the answer is affirmative, what measurements need be taken in the various populations and how they ought to be combined to produce a consistent estimate of the causal effect in the target environment. Related problems concerning generalization across populations will be outlined. (Received September 17, 2013)

1096-62-2481 **Jan Mandel*** (jan.mandel@ucdenver.edu), University of Colorado Denver, Campus Box 170, PO Box 173364, Denver, CO 80217-3364, and **Jonathan D. Beezley**, **Loren Cobb** and **Evan Kwiatkowski**. *Convergence of the ensemble Kalman filter in the large sample limit and in high and infinite dimension.*

The ensemble Kalman filter is often used in weather forecasting, oceanography, and other applications. Convergence to the filtering distribution in the large ensemble asymptotics is of particular interest in the case of a high-dimensional state space. It is commonly believed that the convergence to the filtering distribution deteriorates with increasing dimension of the state space (the "curse of dimensionality"). Yet, modest ensemble sizes are often sufficient in geoscience applications even for very large problems, where the state consists of solutions of partial differential equations discretized on large grids. The reason for this behavior becomes clear when the convergence of the state probability distribution is expressed in the appropriate function space. We provide a convergence analysis that is independent of the dimension of the state space, and remains valid in infinite-dimensional Hilbert space. The data is either finite dimensional, or the data error is white noise, which keeps the filter stable. Versions of the analysis apply to the ensemble Kalman filter with perturbed data, and to unbiased ensemble square root filters. This work was supported by NSF grants EGS-0835579, DMS-1216481, and GACR grant 13-34856S. (Received September 17, 2013)

1096-62-2558 **Mingfei Li*** (mli@bentley.edu), 175 Forest Street, Waltham, MA 02451. *A Primary Study of Bisphosphonate Medications on Osteopathic Fractures for Male Patients in VA Healthcare System.* Preliminary report.

Among the male patients treated in the VA healthcare system from FY2005 to 2009, over 97,000 have been diagnosed with osteoporosis and /or osteopathic fractures and prescribed with bisphosphonate (BP) therapy. In total, 85,212 subjects met the inclusion criteria with a mean age of 72 years, 33.2% not married, and on average there are 3 medical comorbidities. Of the mental health co-morbidities, 13.8% had depression, 3.7% alcohol problems. Results are reported using multivariate logistic regression models. By using national VA claims data, we found that in males with osteoporosis and/or osteoporotic fracture(s), adherence (medication possession ratio) to BP therapy was lowest in those who had the diagnoses of both depression and alcohol problems (P<0.0001, OR (1.40 1.77)), with lower adherence to BP therapy. Results also indicate that prior fractures lead to a higher risk of fracture in those with lower adherence (P-value<0.0001, OR (1.37, 1.54)). The results indicate the importance of adherence in reducing the risk of fracture and demonstrate the usefulness of large administrative claims data bases in addressing important clinical questions. (Received September 17, 2013)

1096-62-2733 **Kay Giesecke** and **Gustavo Schwenkler*** (gas@bu.edu), Boston University School of Management, 595 Commonwealth Ave, Boston, MA 02115. *Filtered Likelihood for Point Processes.* Preliminary report.

We develop likelihood estimators of the parameters of a marked point process and of incompletely observed explanatory factors that influence the arrival intensity and mark distribution. We provide conditions guaranteeing consistency and asymptotic normality as the sample period grows. We also establish an approximation to the likelihood and analyze the convergence and asymptotic properties of the associated estimators. We apply these estimators in an empirical study of the sources of corporate default clustering in the United States. Both

frailty and contagion, by which the default by one firm has a direct impact on the health of other firms, are significant sources of default clustering between 1970 and 2012. These findings have important implications for risk management and the regulation of financial markets. (Received September 18, 2013)

1096-62-2781 **Sayan Mukherjee*** (mkl@ams.org). *Geometry in statistical inference.*
Geometric approaches to data analysis including manifold learning, subspace inference, factor models, and inferring covariance/positive definite matrices. Applications will be used to highlight methodologies. (Received October 15, 2013)

1096-62-2782 **Sayan Mukherjee*** (mkl@ams.org). *Topology in statistical inference.*
Probabilistic perspectives on topological summaries of data such as persistence homology and inference of topological summaries based on the Hodge operator and the Laplacian on forms. Again applications will be used to highlight methodologies. (Received October 15, 2013)

65 ► Numerical analysis

1096-65-189 **Michaela J. Kubacki*** (mjk63@pitt.edu), Department of Mathematics, University of Pittsburgh, 301 Thackeray Hall, Pittsburgh, PA 15260. *Uncoupling Groundwater-Surface Water Flow Using Partitioned Methods.*
The Stokes-Darcy equations arise in many environmental problems, such as tracking groundwater-surface water contamination. Partitioned methods for evolutionary Stokes-Darcy equations uncouple the system so that at each time step we solve separate ground- and surface water flow problems using codes optimized for the physics in each sub-domain. Challenges include finding methods that converge within a reasonable amount of time, are stable when the physical parameters of the flow are small, and maintain stability and accuracy along the interface. An analysis of the Crank-Nicolson Leapfrog scheme, a higher order numerical method, gives rise to a CFL-type condition for stability and convergence. Numerical tests confirm the results of the analysis. The method is improved with the addition of stabilizing terms and can then be coupled with convection-diffusion equations to model the transport of contaminants. (Received August 14, 2013)

1096-65-195 **Paul R Bouthellier*** (pbouthe@pitt.edu), 504 East Main Street, Titusville, PA 16354.
How Calculators Calculate: The Good, The Bad, The Truly Ugly-A Hands-On Tour.
Bring your calculators and let the fun begin. In this talk we shall consider two related topics: First are examples of where the results from our calculators are either flat-out wrong or at least appear to be wrong. These errors come from limited internal accuracy, limited digits on the display, and problematic internal mathematical algorithms (for root-finding, derivatives, integrals, etc...). Often, such errors are a great way to start discussions about concepts in calculus and numerical analysis courses. Secondly we shall show some algorithms which calculators can use to efficiently calculate functions such as sin(x), cos(x), tan(x), ln(x), and exponential functions. These algorithms will show how beautiful and practical mathematical algorithms can be used in devices which students use every day. (Received August 15, 2013)

1096-65-347 **Nan Jiang*** (njiang@usd.edu), Math Dept., 414 E. Clark St., Vermillion, SD 57069. *The Convergence of a Class of Third Order Schemes for Conservation Laws.* Preliminary report.
Yang's wavewise entropy inequality [SIAM. J. Numer. Anal. 36 (1999) No. 1, 1-31] is verified for a class of third order methods which, under a mild technique condition, guarantees the convergence of the methods to the entropy solutions of convex conservation laws in one-dimensional scalar case. These schemes, constructed by S. Osher and S. Chakravarthy [Journal of Oscillation theory, computation, and methods of compensated compactness, (1986), 229-274], are based on unwinding principle and use E-schemes as building blocks with simple flux limiters, without which all of them are even linearly unstable. The total variation diminishing property of these methods was established in the original work of S. Osher and S. Chakravarthy. (Received August 29, 2013)

1096-65-351 **Bjorn Engquist**, **Brittany Froese*** (bfroese@math.utexas.edu) and **Richard Tsai**.
Fast Sweeping Methods for Hyperbolic Systems of Conservation Laws at Steady State.
Fast sweeping methods have become a useful tool for computing the solutions of static Hamilton-Jacobi equations. By adapting the main idea behind these methods, we describe a new approach for computing steady state solutions to systems of conservation laws. By exploiting the flow of information along characteristics, these fast sweeping methods can compute solutions very efficiently. Furthermore, the methods capture shocks sharply

by directly imposing the Rankine-Hugoniot shock conditions. We present numerics for several one- and two-dimensional examples to illustrate the use and advantages of this approach. (Received August 29, 2013)

1096-65-396 **Weidong Chen*** (`wchen@math.uga.edu`), Math Dept, University of Georgia, Athens, GA 30602. *Regularized Restoration for Two Dimensional Band-Limited Signals.*

In this paper the ill-posedness of restoring lost samples is discussed in the two dimensional case. The restoration algorithm by Shannon's Sampling Theorem is analyzed. A regularized restoring algorithm for two dimensional band-limited signals is presented. The convergence of the regularized restoring algorithm is studied and compared with the restoration algorithm by Shannon's sampling theorem in the two dimensional case. (Received September 01, 2013)

1096-65-499 **Fred J. Hickernell*** (`hickernell@iit.edu`), E1-208, 10 W. 32nd Street, Department of Applied Mathematics, Illinois Institute of Technology, Chicago, IL 60616. *Guaranteed Adaptive, Automatic, Quadrature.*

Automatic quadrature algorithms claim to provide an approximation to the integral that is within a user-specified error tolerance of the true integral. Most comprehensive numerical computing environments, such as MATLAB, Chebfun, Mathematica, NAG, and R, include automatic quadrature algorithms. Typically, these algorithms are adaptive, meaning that they adjust their computational effort based on the perceived difficulty of the problem. Unfortunately, these adaptive algorithms come with no guarantees, i.e., sufficient conditions on the integrands ensuring that the algorithm works as advertised. Here we describe an adaptive trapezoidal algorithm for integration that is guaranteed to provide the correct answer for cones of integrands. The computational cost has optimal convergence order. This new algorithm has consequences for how numerical quadrature should be taught. It also illustrates a new paradigm for constructing adaptive, automatic numerical algorithms. (Received September 05, 2013)

1096-65-575 **Lina Ma*** (`ma6@purdue.edu`), **Ting Cheng** and **Jie Shen**. *Spectral method for a 3D Spherical Interface Dynamo Equation.*

We consider a spectral method to solve a three-dimensional, nonlinear, time-dependent spherical interface dynamo system. Based on the analysis of continuous case, a fully discrete spectral method to approximate the problem is proposed and stability and the convergence of the numerical scheme are studied. Numerical experiments are also carried out to show the efficiency of the scheme. (Received September 06, 2013)

1096-65-622 **shimao fan*** (`shimao@illinois.edu`), 115 Sterling Ct, APT 302, savoy, IL 61874. *Data-Fitted Generic Second Order Macroscopic Traffic Flow Models and Model Accuracy on Real Data.*

The Aw-Rascle-Zhang (ARZ) model is a "second order" macroscopic traffic model that possesses a family of fundamental diagram curves, rather than a single one as in the "first order" Lighthill-Whitham-Richards (LWR) model. Hence, the ARZ model can agree better with historical fundamental diagram data, especially for set-valued regime in congested traffic. However, the ARZ model also has some obvious shortcomings, e.g., it possesses various stagnation traffic densities. To overcome these drawbacks, we consider a Generalized ARZ model (GARZ), fitted to real historic traffic data. A systematic approach to generate more realistic "second order" models is proposed, under a generic framework. Based on GARZ model, we propose a phase-transition-like model, that allows flow rate curves to coincide in the free flow regime. To investigate to which extent the generalized models improves the prediction accuracy of models, we perform a comparison of data-fitted generalized models with two types of data-fitted LWR models and their second order ARZ generalizations, via a three-detector problem test. We consider two different kinds of traffic data during model construction and validation: detector data and vehicle trajectory data. (Received September 08, 2013)

1096-65-627 **Eitan Tadmor***, Center Sci. Computation and Math. Modeling, CSCAMM, CSIC Bldg. 406, University of Maryland, College Park, MD 20742, and **Claude Bardos**, Laboratory Jacques Louis Lions, University of Paris 7- Denis Diderot, Paris, France. *Stability and spectral convergence of Fourier method for nonlinear problems.*

The inviscid Burgers' equation and the incompressible Euler equations are prototypical problems with quadratic nonlinearities. We discuss their approximation by the Fourier method. It comes in two main flavors. One is the spectral Fourier method. The other is the 2/3 pseudo-spectral Fourier method, where one removes the highest 1/3 portion of the spectrum; this is often the method of choice to maintain the balance of quadratic energy and avoid aliasing errors.

We prove that as long as the underlying solutions of Burgers and Euler equations have a minimal spatial regularity, then (both versions of-) the Fourier method are stable and hence spectrally convergent. But after a critical time at which the underlying solution lacks sufficient smoothness, then both methods exhibit nonlinear instabilities which are realized through spurious oscillations.

In particular, after shock formation in inviscid Burgers' equation, the total variation of bounded Fourier solutions *must* grow unboundedly. We stipulate that the analogous situation occurs with the 3D incompressible Euler equations: the contrast between the energy conserving Fourier method and the energy dissipating Onsager solutions is reflected through spurious oscillations. (Received September 08, 2013)

1096-65-720 **Zheng Chen*** (zheng_chen@brown.edu) and **Chi-Wang Shu**. *Recovering exponential accuracy from collocation point values of smooth functions with end-point singularities.*

Gibbs phenomenon is the particular manner how a global spectral approximation of a piecewise analytic function behaves at the jump discontinuity. The truncated spectral series has large oscillations near the jump, and the overshoot does not decay as the number of terms in the truncated series increases. There is therefore no convergence in the maximum norm, and convergence in smooth regions away from the discontinuity is also slow. A methodology was proposed to completely overcome this difficulty in the context of spectral collocation methods, resulting in the recovery of exponential accuracy from collocation point values of a piecewise analytic function. In this talk, we show how to extend this methodology to handle spectral collocation methods for functions which are analytic in the open interval but have singularities at end-points. With this extension, we are able to obtain exponential accuracy from collocation point values of such functions. The proof is constructive and uses the Gegenbauer polynomials $C_n^\lambda(x)$. The result implies that the Gibbs phenomenon can be overcome for smooth functions with endpoint singularities. (Received September 09, 2013)

1096-65-725 **A. R. Hungria*** (allanh@udel.edu), Newark, DE 19711, and **J. D. Mireles James** and **J. P. Lessard**. *Computer-Assisted Proof of Periodic Solutions of ODE and PDE systems.*

We examine a computer assisted method for proving existence and uniqueness of periodic solutions of some ordinary and partial differential equations. The solutions may be periodic in space, time, or both. The method is a posteriori, i.e., we start with a reasonable numerical approximation and use it to formulate and check some key hypotheses. If these are satisfied, then the theorem follows, and the information gained is two-fold:

1) We obtain rigorous proof of the abstract existence (and uniqueness) of a periodic solution. 2) We obtain accurate quantitative information about the solution, such as bounds on its Fourier coefficients and domain of analyticity.

I will sketch the method and discuss a few example applications. (Received September 09, 2013)

1096-65-776 **Jangwoon Lee*** (llee3@umw.edu), University of Mary Washington, Department of Mathematics, 1301 College Ave, Fredericksburg, VA 22401, and **Jeehyun Lee** and **Yoongu Hwang**. *An Optimization Based Domain Decomposition Method for PDEs with Random Inputs.*

An optimization-based domain decomposition method for stochastic elliptic partial differential equations is presented. The main idea of the method is a constrained optimization problem for which the minimization of an appropriate functional forces the solutions on the two subdomains to agree on the interface; the constraints are the stochastic partial differential equations. The existence of optimal solutions for the stochastic optimal control problem is shown as is the convergence to the exact solution of the given problem. We prove the existence of a Lagrange multiplier and derive an optimality system from which solutions of the domain decomposition problem may be determined. Finite element approximations to the solutions of the optimality system are defined and analyzed with respect to both spatial and random parameter spaces. Then, the results of some numerical experiments are given to confirm theoretical error estimate results. (Received September 10, 2013)

1096-65-781 **Tim Chartier*** (tichartier@davidson.edu), P.O. Box 6908, Department of Mathematics, Davidson, NC 28035, and **Austin Totty** (atotty@hammondschool.org). *Chocolate covered pi.*

Have an urge for chocolate? Why not use the tasty morsels first to approximate an integral? This talk shows how to use chocolate chips to approximate an integral. The heart of the math lies in how we choose which variety (milk or white chocolate) of chocolate chip to use in our computation. This method motivates the rectangle method for numerical integration. A simple alteration of the method improves the algorithm's accuracy and motivates the Trapezoidal rule. We will also compare the accuracy of these classical methods of numerical integration to the use of candy mosaics for integration. (Received September 10, 2013)

1096-65-847 **Dr. Atma R Sahu*** (asahu@coppin.edu), 7704 Mystic River Terrace, Glenn Dale, MD 20769. *Fuzzy Logic: A Departure from Mathematical Modeling to Computing Problem Solving.*

This presentation will walk the fuzzy logic users from its' inception story by Lotfi Zadeh, a professor at the University of California at Berkley to today's fuzzy logic approaches as applied to control nonlinear systems that would be difficult or impossible to model mathematically. Additionally, this fuzzy logic methodology discourse will show AMS conference attendees, some engineering applications,such as fuzzy logic thermostats system 's usage to control the heating and cooling, fuzzy logic methodology use in industrial automation; and later illustrate it's usage in decision making process and in data mining that uses, to some extent, many machine learning methods. (Received September 10, 2013)

1096-65-853 **Thomas Strohmer*** (strohmer@math.ucdavis.edu), Department of Mathematics, University of California, Davis, Davis, CA 95616. *Eigenvector Localization, Random Matrices, and Banach Algebras.* Preliminary report.

The need to understand when and how well eigenvectors of matrices are localized, arises in a variety of areas as diverse as Massive Data Analysis, Random Matrix Theory, and Condensed Matter Physics (Anderson localization). Yet, our understanding of the localization of eigenvectors is surprisingly limited, given the fact that more and more instances emerge where such localization has been observed empirically, and a thorough understanding of this phenomenon is expected to yield crucial insights. In this talk I will make a first step toward developing a comprehensive qualitative and quantitative mathematical framework for characterizing the localization behavior of eigenvectors. The approach combines tools from Harmonic Analysis, Banach Algebras, and Random Matrix Theory. I will then briefly discuss similar localization results for other matrix factorizations beyond the singular value decomposition, and conclude with some open problems. (Received September 10, 2013)

1096-65-1009 **Catherine A Bliss*** (catherine.bliss@uvm.edu), Department of Mathematics & Statistics, Vermont Complex Systems Center, 16 Colchester Ave., Burlington, VT 05405, and **Morgan R Frank**, **Chris M Danforth** and **Peter S Dodds**. *Covariance Matrix Adaptation Evolution Strategy for Link Prediction in Dynamic Social Networks.*

Many real world, complex phenomena have underlying structures of evolving networks where nodes and links are added and removed over time. A central scientific challenge is the description and explanation of network dynamics, with a key test being the prediction of short and long term changes. For the problem of short-term link prediction, existing methods attempt to determine neighborhood metrics that correlate with the appearance of a link in the next observation period. Recent work has suggested that the incorporation of topological features and node attributes can improve link prediction. We provide a novel approach to predicting future links by applying Covariance Matrix Adaptation Evolution Strategy to optimize weights which are used in a linear combination of sixteen neighborhood and node similarity indices. We examine a large dynamic social network with over 10^6 nodes (Twitter Reciprocal Reply Networks), both as a test of our general method and as a problem of scientific interest in itself. Our methods exhibit fast convergence and, to our knowledge, strongly outperforming all extant methods. Based on our findings, we suggest possible factors which may be driving the evolution of Twitter reciprocal reply networks. (Received September 12, 2013)

1096-65-1015 **Jonathan D Hauenstein*** (hauenstein@ncsu.edu), 3152 SAS Hall, Box 8205, NC State University, Raleigh, NC 27695-8205, and **Alessandra Bernardi** and **Noah S Daleo**. *Homotopy continuation and signal decomposition.* Preliminary report.

One can model an observed input signal as the sum of various incoming signals together with noise. By having each incoming signal be a rank one tensor, the observed input is a numerical approximation of a sum of rank one tensors. In this talk, we describe using numerical algebraic geometric techniques based on homotopy continuation to attempt to recover the individual rank one tensors from the observed signal. (Received September 12, 2013)

1096-65-1046 **Tiara D. Turner*** (tdturner@umes.edu), 1 College Backbone Road, Department of Math and Computer Science, Kiah Hall 1122, Princess Anne, MD 21853, **Jiguang Sun** (jiguangs@mtu.edu), Fisher 313, Department of Mathematical Sciences, 1400 Townsend Drive, Houghton, 49931, and **Xia Ji**. *A Mixed Finite Element Method for Helmholtz Transmission Eigenvalues.*

The transmission eigenvalue problem has important applications in inverse scattering. Since the problem is non-self-adjoint, the computation of transmission eigenvalues needs special treatment. Based on a fourth-order reformulation of the transmission eigenvalue problem, a mixed finite element method is applied. The method has two major advantages: 1) the formulation leads to a generalized eigenvalue problem naturally without the need to invert a related linear system, and 2) the nonphysical zero transmission eigenvalue, which has an infinitely dimensional eigenspace, is eliminated. To solve the resulting non-Hermitian eigenvalue problem, an iterative algorithm using restarted Arnoldi method is proposed. To make the computation efficient, the search interval is decided using a Faber-Krahn type inequality for transmission eignevalues and the interval is updated at each iteration. The algorithm is implemented using Matlab. The code can be easily used in the qualitative methods in inverse scattering and modified to compute transmission eigenvalues for other models such as elasticity problem. (Received September 12, 2013)

1096-65-1094 **Nora Stack*** (nhstack@smcm.edu), Campus Center #2721, 16800 Point Lookout Road, St. Mary's City, MD 20686, **Walter Cai** (wzc2@cornell.edu), 408 Dryden Rd. APT 2, Ithaca, NY 14850, **Ana Cristina Perez-Gea** (gea9109@hotmail.com), Brisa 287, Jardines del Pedregal, Álvaro Obregón 01900, Mexico, and **Scott Manifold** (scott.manifold@email.ucr), 9508 Taft Street, Riverside, CA 92508. *Fast Generation and Tracking of GPS Visibility and Dilution of Precision Regions Using Level Set Methods.*

Two major performance measures of GPS systems are visibility and Dilution of Precision (DOP). Visibility is defined by regions that share a direct line of sight with sufficiently many satellites in orbit, while DOP is a metric correlated with GPS user error. Our hypothesis is that implementing Level Set Methods to measure visibility and DOP will prove to be more time efficient and equally as accurate as the systems that are currently used by analysts at The Aerospace Corporation.

Drawing on current literature and working jointly with The Aerospace Corporation, two separate strategies were investigated and implemented with regards to the problem framework; a Static Approach and a Dynamic Approach. Furthermore, variations to choice of spatial scheme, point set representation, mapping projection, and many other aspects were explored to study effects on computational efficiency and accuracy on performance simulations. From this point, efforts to implement and test the viability of different numerical optimization schemes, in relation to the problem framework and Matlab software, were pursued. Initial results of these techniques have shown to be promising with regards to analysis and calculation of GPS Satellite Visibility Zones and GPS Dilution of Precision metrics. (Received September 12, 2013)

1096-65-1114 **Helga Nutz*** (nutz@mathematik.uni-kl.de), University of Kaiserslautern, 67663 Kaiserslautern, Germany. *A multiscale spline approach for the tensorial satellite gravity gradiometry problem.*

The launch of the satellite GOCE by the European Space Agency (ESA) in 2009 was the initial point for realizing the concept of Satellite Gravity Gradiometry (SGG). The satellite carries a set of accelerometers which measure the components of the gravity field along all three axes and ensure a coverage of the entire Earth with gravity measurements, however, at orbital altitude. Since the accelerometers measure the relative accelerations between two test masses they provide information about the Hesse tensor of the gravitational potential. In the context of inverse problems, the calculation of the gravitational potential at the Earth's surface from its second order derivatives at satellite's height turns out to be exponentially ill–posed and, thus, requires specific tensorial procedures for its solution. The talk presents a spline–based regularization method for tensorial data to overcome the calamities of the ill-posedness, thereby providing a "zooming–in" technique of modeling the gravitational potential from global to local scale.

Satellite Gravity Gradiometry as Tensorial Inverse Problem, W. Freeden, H. Nutz, Int. J. Geomath.(2), 177-218, 2011;

A Multiscale Spline Approach to Tensorial Satellite Gravity Gradiometry, W. Freeden, H. Nutz (submitted). (Received September 13, 2013)

1096-65-1131 **Brianna R Cash*** (brcash@math.umd.edu), 3103 Mathematics Building, College Park, MD 20742-4015, and **Dianne O'Leary**. *User-Aided Space Transformation of Color Images for Improved Edge Detection.* Preliminary report.

There are many accepted and well used edge detection methods that are fast and easy to implement when applied to gray scale images. Unfortunately gray scale images only capture the light intensity of the continuous scene, losing information about the colors (chroma). Although it is stated in the literature that 90% of the information in color images is captured in the gray scale image, there are foreseeable applications where that additional 10% is critical in finding the relevant edges. This loss of information can be important but it comes at a cost as color images are measured in three color coordinates versus single coordinate gray scale images. This work develops a new color space by user aided transformation of the three coordinate space into a single coordinate space where the color discontinuities of interest are captured. This method is applied to finding edges of spots of erythema (reddening) in images of skin after skin irritation. In this application background skin color/tone (an unaffected patch of skin) is known and can be used to help detect deviation. Example applications of this work are in monitoring the spread of infection, measuring the effectiveness of treatment for ulcers and other skin conditions, and cataloging skin artifacts such as moles. (Received September 13, 2013)

1096-65-1180 **Matthew Reyna*** (reynam@rpi.edu), Department of Mathematical Sciences, Amos Eaton 301, 110 8th Street, Troy, NY 12180, and **Fengyan Li** (lif@rpi.edu), Department of Mathematical Sciences, Amos Eaton 301, 110 8th Street, Troy, NY 12180. *On the bounds and time-step restrictions for the DG and central DG spatial operators.* Preliminary report.

It is observed that the central discontinuous Galerkin (DG) method often admits larger time steps than a DG method of the same order of accuracy in simulating hyperbolic conservation laws. To understand this, we start with DG and central DG spatial discretizations for a linear advection equation, and we show that the norm of the DG spatial operator grows quadratically with the order of the method while that of the central DG operator grows only linearly. When these semi-discrete methods are further combined with a locally-stable temporal discretization, we follow Kreiss-Wu's theory and obtain sufficient conditions on the time step to ensure numerical stability. We validate our results numerically, and we also extend them to general linear hyperbolic equations. (Received September 13, 2013)

1096-65-1181 **Emily J Evans*** (ejevans@math.byu.edu), Provo, UT 84602, and **Michael A. Scott**. *The Mathematics of Hierarchical T-splines.*

Hierarchical B-splines were originally introduced in the CAD community nearly thirty years ago. Currently, hierarchical spline techniques are restricted to tensor product B-splines and NURBS. This restriction, coupled with the difficulty of encoding geometric information in the hierarchy, has greatly hampered their adoption as a CAD tool. To overcome these limitations we have extended analysis-suitable T-splines to the hierarchical unstructured regime. In this way, the design advantages of T-splines can be leveraged while introducing the analysis advantages of easily controlled hierarchies of locally refined analysis-suitable T-spline spaces. We present a simple characterization and construction for hierarchical analysis-suitable T-splines and demonstrate their potential as a basis for adaptive isogeometric analysis. (Received September 13, 2013)

1096-65-1263 **Janitha Gunatilake*** (janitha.gunatilake@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Broadway & Boston, Lubbock, TX 79409-1042, and **Eugenio Aulisa**. *A multilevel domain decomposition algorithm using the hierarchical element structure.* Preliminary report.

We consider hierarchical bases based on Legendre polynomials where the finite element basis for polynomial order p, $\mathcal{B}^p$ has the property $\mathcal{B}^p \subset \mathcal{B}^{p+1}$ for all p. We present a multilevel domain decomposition algorithm for elliptic type problems based on hierarchical elements. This method combines the features of domain decomposition, geometric multigrid method and hierarchical element structure. In this approach, we consider a nonconforming mesh as a finite union of conforming meshes defined on subdomains of the original domain and use the geometric multigrid techniques to solve the problem. The use of a hierarchical basis avoids the complication of building recursive grid structures with respect to a geometric multigrid and results in simpler intergrid operators. As far as $p-$ and $hp-$adaptivity is concerned, hierarchical elements allow for locally nonuniform distribution of the order of polynomial approximation more easily than nodal elements. This algorithm is implemented in 2 and 3 dimensions. (Received September 14, 2013)

1096-65-1284 **Xiangxiong Zhang*** (zhangxx@math.mit.edu), Math Dept., MIT, Cambridge, MA 02139. *Eventual linear convergence of the Douglas-Rachford iteration for basis pursuit.*

We provide a simple analysis of the Douglas-Rachford splitting algorithm in the context of ℓ^1 minimization with linear constraints, and quantify the asymptotic linear convergence rate in terms of principal angles between relevant vector spaces. In the compressed sensing setting, we show how to bound this rate in terms of the restricted isometry constant. More general iterative schemes obtained by ℓ^2-regularization and over-relaxation including the dual split Bregman method are also treated, which answers the question how to choose the relaxation and soft-thresholding parameters to accelerate the asymptotic convergence rate. We make no attempt at characterizing the transient regime preceding the onset of linear convergence. (Received September 14, 2013)

1096-65-1307 **Adekunle Ademola Araromi*** (adekunle_yem@yahoo.ca), P.O.Box 491, Oyo, Oyo State, Nigeria., Nigeria. *Modified variational iterative method for solving the linear and nonlinear Klein-Gordon equations.*

In this paper, modified variational iterative method (VIM) is considered as an alternative method for solving the linear and nonlinear Klein-Gordon equations. This method is based on the use of modified variational iterative method to solve some physical models of Klein-Gordon equations. Using the variational iterative method, it is shown that the present approach is highly accurate and converges rapidly. (Received September 14, 2013)

1096-65-1355 **Xuebo Yu*** (xyu@math,kent.edu), Kent, OH 44242, and **Lothar Reichel** (reichel@math.kent.edu), Kent, OH 44242. *A Reduction Method For Matrix Pairs with Application to Tikhonov Regularization.*

Abstract. We describe a novel method for reducing a pair of large matrices $\{A, B\}$ to a pair of small matrices $\{H^A, H^B\}$. Applications to Tikhonov regularization of large linear discrete ill-posed problem are described. In these problems the matrix A represents the discretization of a compact integral operator and B is a regularization matrix.

Key words. Krylov subspace, ill-posed problem, regularization matrix, Tikhonov regularization. (Received September 15, 2013)

1096-65-1359 **S Chakraverty*** (sne_chak@yahoo.com), Professor and Head, Department of Mathematics, National Institute of Technology Rourkela, Rourkela, Odisha 769008, India, and **Smita Tapaswini** (smitatapaswini@gmail.com), Senior Res. Fellow Department of Mathematics, National Institute of Technology Rourkela, Rourkela, Odisha 769008, India. *New Fibonacci Type Collocation Approach for n-th Order Uncertain Differential Equations.*

System parameters in governing differential equations of physical problems are in general considered as crisp or exact. But, rather than the particular value we may have only the vague, imprecise or incomplete information about the parameters being a result of errors in measurement, observation and experiment etc. which are uncertain in nature. These uncertainties can be modelled through probabilistic, interval or fuzzy theories. Unfortunately, probabilistic methods may not able to deliver reliable results at the required precision without sufficient experimental data. As such in the recent decades, interval analysis and fuzzy theory are becoming powerful tools for real life applications. Accordingly, this paper proposes a new procedure for numerical solution of th order fuzzy differential equations using collocation type of method. Here, the solution of a fuzzy differential equation is expressed as a linear combination of the Fibonacci polynomials in the basis set involving unknown fuzzy constants. The applicability and effectiveness of proposed technique is shown by known example problems and compared with the exact results to illustrate the efficiency and reliability of the method. . (Received September 15, 2013)

1096-65-1370 **Wenyuan Wu** (wuwenyuan@cigit.ac.cn) and **Zhonggang Zeng*** (zzeng@neiu.edu), Department of Mathematics, Northeastern Illinois University, Chicago, IL 60625. *The numerical factorization of polynomials.*

Polynomial factorization is a basic algebraic operation and an enduring subject of study in computer algebra. In contrast to the conventional symbolic factorization, the objective of numerical factorization is to calculate irreducible factors accurately from empirical data using floating point arithmetic. This talk presents the formulation and fundamental theorems of the numerical factorization as well as an algorithmic framework. Implementation, software and computing experiment will also be discussed. (Received September 15, 2013)

1096-65-1380 **Maria Emelianenko*** (memelian@gmu.edu), **Claudio Torres** and **Dmitry Golovaty**. *Computational modeling of polycrystals: accuracy and sensitivity analysis.*

The study of the effect of various microscopic features on the meso- and macroscopic behavior of polycrystalline materials undergoing coarsening has received a lot of attention due its extreme importance in technological applications. From computational point of view, various numerical simulation models exist to date, but little has been done so far to investigate the effect of numerical and modeling parameters on the statistics generated by these codes. In fact, very often numerical limitations of such models are not rigorously investigated, which puts them at risk of producing inaccurate predictions. This work represents the first attempt to fill this gap by conducting a thorough numerical investigation of a set of 2-d grain growth simulation models called vertex models, as well as some related 1-d models. This study sheds light onto several important questions, such as whether or not statistics is affected by the choice of grid resolution, grain boundary flipping rules and dynamical features of the model. Rigorous estimates of the flipping rates and steady state distributions are also obtained. Extensive comparison is performed against numerical codes available in the literature as well as experimental data, for both isotropic and anisotropic grain boundary energy. (Received September 15, 2013)

1096-65-1467 **Treena Basu***, basut@rhodes.edu, and **Hong Wang**, hwang@math.sc.edu. *Fast Solution Methods for the Space-Time Fractional Diffusion Equations.*

Fractional diffusion equations model phenomena exhibiting anomalous diffusion that can not be modeled accurately by the second order diffusion equations.Because of the non-local property of fractional differential operators, the numerical methods have full coefficient matrices which require storage of $O(N^2)$ and computational cost of $O(N^3)$, where N is the number of grid points.

Together we develop a fast finite difference method for the one-dimensional space and time fractional diffusion equation, which only requires storage of $O(N)$ and computational cost of $O(NlogN)$, while retaining the same accuracy and approximation property as the regular finite difference method. Numerical experiments are presented to show the utility of the method.

For example, with 1024 computational nodes, the new scheme developed for the one-dimensional problem has about 40 times of CPU reduction than the standard scheme. (Received September 15, 2013)

1096-65-1474 **Andreas C. Aristotelous***, aaristot@math.duke.edu, and **Ohannes Karakashian** and **Steven M. Wise**. *Discontinuous Galerkin Methods for a Modified Cahn-Hilliard Equation and a Diffuse Interface Model of Tumor Growth.*

We present a mixed discontinuous galerkin finite element (DG-FE), convex splitting scheme for a modified Cahn-Hilliard (CH) equation. Unconditional energy stability and unique solvability, as well as optimal convergence, are proven for the scheme. An efficient nonlinear multigrid algorithm is used to solve the discrete equations.
Also, a spatially adaptive, primitive-variable DG-FE scheme for a CH-type diffuse interface model for tumor growth is presented. Convergence under mesh modification is demonstrated, and simulation results are provided. (Received September 15, 2013)

1096-65-1559 **Howard C Elman*** (elman@cs.umd.edu) and **Minghao Wu**. *Robust Methods for Eigenvalue Computations in Linear Stability Analysis.*

In linear stability analysis of a large-scale dynamical systems, we need to compute the rightmost eigenvalue(s) for a series of large generalized eigenvalue problems. Existing iterative eigenvalue solvers are not robust when no estimate of the rightmost eigenvalue(s) is available. In this study, we show that such an estimate can be obtained from Lyapunov inverse iteration applied to a special eigenvalue problem of Lyapunov structure. An analysis that explains the fast convergence of this algorithm observed in numerical experiments is provided, based on which we propose a more efficient and robust algorithm. Furthermore, we generalize the same idea to a deflated version of this Lyapunov eigenvalue problem and propose an algorithm that computes a few rightmost eigenvalues for the eigenvalue problems arising from linear stability analysis. (Received September 16, 2013)

1096-65-1627 **Geoffrey R Dillon*** (geoffrey.dillon@ttu.edu), Texas Tech University, Deptartment of Mathematics and Statistics, Broadway and Boston, Lubbock, TX 79409, **Victoria Howle** (victoria.howle@ttu.edu), Texas Tech University, Deptartment of Mathematics and Statistics, Broadway and Boston, Lubbock, TX 79409, and **Robert C Kirby** (robert_kirby@baylor.edu), Baylor University, Department of Mathematics, One Bear Place #97328, Waco, TX 76798. *Block preconditioners for coupled physics problems.*

Standard incompressible flow models are increasingly becoming one component of larger systems of equations, whether by incorporating additional nonlinear effects or by coupling to other processes. We consider approximate block factorization preconditioners based on the systems that arise after linearization and finite element discretization. In addition we incorporate existing preconditioners for Navier-Stokes (such as those of Elman, et al.) with a novel approximation to the Schur complement to obtain preconditioners for the Benard convection problem and others. (Received September 16, 2013)

1096-65-1683 **Tianran Chen*** (chentia1@msu.edu) and **Tien-Yien Li** (li@math.msu.edu). *Path tracking algorithms for homotopy continuation methods in weighted projective spaces.*

Solving systems of polynomial equations is an important problem in mathematics with a wide range of applications in many fields. The homotopy continuation method is a large class of reliable and efficient numerical methods for solving systems of polynomial equations. An essential component in the homotopy continuation method is the path tracking algorithm for tracking smooth paths of one real dimension. While existing path tracking algorithms works inside $\mathbb{C}^n$ or the complex projective space $\mathbb{CP}^n$, in this talk we generalize the path tracking algorithms to weighted projective spaces by exploring the Riemannian structure of its smooth part. Results from numerical experiments have shown that these algorithms can be useful for solving quasi-homogeneous systems of polynomial equations. (Received September 16, 2013)

1096-65-1719 **Hailong Guo**, **Zhimin Zhang** and **Ren Zhao*** (renzhao@wayne.edu), 656 W. Kirby, 1250 FAB, Department of Mathematics, Wayne State University, Detroit, MI 48202. *Robust Polynomial Preserving Recovery On Boundary.*

Two new strategies of gradient recovery technique for boundary are proposed and analyzed. It is proved to be superconvergent under uniform meshes for both strategies. Numerical experiments are conducted to demonstrate the robustness of the two strategies. In addition, numerical test shows that these recovery strategies are efficient and superconvergent under adaptive mesh. (Received September 16, 2013)

1096-65-1832 **Adamou Made Fode*** (afode@bgsu.edu), 450 Mathematics and Sciences Building, Bowling Green, OH 43403. *Numerical Smoothness and its Application to Error Analysis for RKDG on the Scalar Nonlinear Conservation Laws.*

Numerical Smoothness is a new concept in the literature of Differential Equations, and it means the smoothness of numerical solutions. Although, the idea of numerical smoothness is not a popular concept in the literature, it is a necessary concept as an early indicator of numerical instability. In this talk, we will show the importance of smoothness indicators and their contribution in the error analysis of a smooth and a non smooth solution to hyperbolic problems. (Received September 16, 2013)

1096-65-1870 **Jakob Hansen*** (jakob.hansen@asu.edu). *Improving conditioning for the electrochemical impedance spectroscopy inverse problem.*

Analysis of the performance of fuel cells often requires finding a distribution function of relaxation times (DRT) from measured electrochemical impedance spectra. This problem, described by a Fredholm integral equation, is inherently ill-posed. Discretization for solution by linear least squares introduces further numerical ill-conditioning. A reformulation of the problem through a change of variables can minimize the effects of this ill-conditioning and improve the quality of problem solutions obtained by Tikhonov regularization. (Received September 16, 2013)

1096-65-1902 **Joscha Gedicke*** (jgedicke@math.lsu.edu), Department of Mathematics and CCT, 216 Johnston Hall, Louisiana State University, Baton Rouge, LA 70803. *A posteriori error estimates for biharmonic eigenvalue problems.* Preliminary report.

Biharmonic eigenvalue problems occur in the analysis of vibrations and buckling of plates. This talk presents a posteriori error estimates for a quadratic C^0-interior penalty method for biharmonic eigenvalue problems. A reliable and efficient a posteriori error estimator for the energy and eigenvalue error is derived. The theoretical results are verified in numerical experiments. (Received September 16, 2013)

1096-65-1940 **Susanne C. Brenner**, **Christopher B. Davis*** (cdav135@lsu.edu) and **Li-Yeng Sung**. *A Partition of Unity Method for an Elliptic Optimal Control Problem with State Constraints.*

State constrained optimal control problems are an important class of problems in science and engineering. In this talk, we propose a partition of unity finite element method for an elliptic optimal control problem with pointwise state constraints on convex polygons. By constructing appropriate local approximation spaces, we are able to show that this method converges optimally. Numerical results are given which show the optimal convergence of this method. (Received September 16, 2013)

1096-65-1943 **Joseph A Eichholz*** (eichholz@rose-hulman.edu), Rose Hulman Institute of Technology, Deptartment of Mathematics, Terre Haute, IN 47803. *A new a posteriori error estimate for numerical solutions of the radiative transport equation.*

The radiative transport equation (RTE) is a linear five-dimensional integro-differential equation with application in medical imaging, heat transfer, and atmospheric physics, to name a few. The relatively high dimensionality and the presence of a non-local integral term make accurate numerical solution of the RTE quite computationally expensive.

In this talk we present new robust and efficient residual type *a posteriori* error estimates for the numerical solution of the RTE in both a natural energy norm and in the L^2 norm.

We use the new error estimates to develop an adaptive discrete-ordinate finite element method, and present numerical results indicating considerable time savings over traditional non-adaptive methods. (Received September 16, 2013)

1096-65-1946 **Anne Gelb** (annegelb@asu.edu), Box 1804, Arizona State University, Tempe, AZ 85287-1804, and **Adita Viswanathan*** (aditya.v@caltech.edu), Department of Applied and Computational Mathematics, California Institute of Technology, Pasadena, CA. *Numerical Approximation Methods for Non-Uniform Fourier Data.*

This talk is about reconstructing compactly supported piecewise smooth functions from non-uniform samples of their Fourier transform. This problem is relevant in applications such as magnetic resonance imaging (MRI) and synthetic aperture radar (SAR).

While the non-uniform FFT (convolutional gridding) algorithm provides a practical way to reconstruct images, it is evident that if the method's parameters, usually determined heuristically, are not properly chosen, then it may not converge. This talk provides a mathematical foundation, through the use of Fourier frames, for reconstructing functions from their non-uniform Fourier data. As a result, numerical convergence and robustness can be guaranteed for various non-uniform sampling schemes typical in MRI. (Received September 16, 2013)

1096-65-1953 **Weihong Guo*** (wxg49@case.edu), 10900 Euclid Avenue, Cleveland, OH 44106. *A convex relaxation segmentation scheme based on shearlets.* Preliminary report.

Image segmentation is an essential problem in imaging science. Non-convex models such as Mumford-Shah and Chan-Vese have been proven to be successful but are hard to implement. We combine convex relaxation methods with L1 shearlet sparsity to efficiently segment images with multi-scale and multi-directional details. The proposed optimization problem is sovled using fast techniques such as Split Bregman, ADMM and FFT. Comparisons with other competitive segmentation methods validate the efficiency of the proposed approach. (Received September 16, 2013)

1096-65-2007 **Xiaozhe Hu*** (hu_x@math.psu.edu), 309 McAllister Buliding, The Pennsylvania Sta, University Park, PA 16802. *Numerical Study for Potential Variation and Ion Transport in Ionic Polymer Membranes.* Preliminary report.

The study of potential variation and ion transport in ionic polymer membranes is very important for understanding membrane charging behavior and transport performance in applications such as electrodialysis. In this work, we numerically solve the Poisson-Boltzmann equation and Poisson-Nernst-Plank equation. Newton's method is applied and geometric multigrid method is developed to solve the coupled Jacobian system. We apply the proposed numerical method to study ionic polymer membrane in contact with electrolyte aqueous solution. Numerical results demonstrate the method's efficiency in practical applications. (Received September 17, 2013)

1096-65-2016 **Bin Zheng*** (bin.zheng@pnnl.gov), Pacific Northwest National Laboratory, 902 Battelle Boulevard, P.O. Box 999, MSIN K7-90, Richland, WA 99352, and **Da Meng**, **Guang Lin** and **Maria L. Sushko**. *Numerical Solution of 3D Poisson-Nernst-Planck Equations Coupled with Classical Density Functional Theory for Modeling Ion and Electron Transport in a Confined Environment.*

We have developed efficient numerical algorithms for solving 3D steady-state Poisson-Nernst-Planck (PNP) equations with excess chemical potentials described by the classical density functional theory (cDFT). The coupled PNP equations are discretized by a finite difference scheme and solved iteratively using the Gummel method with relaxation. The Nernst-Planck equations are transformed into Laplace equations through the Slotboom transformation. Then, the algebraic multigrid method is applied to efficiently solve the Poisson equation and the transformed Nernst-Planck equations. A novel strategy for calculating excess chemical potentials through fast Fourier transforms is proposed, which reduces computational complexity from $O(N^2)$ to $O(N \log N)$, where N is the number of grid points. Integrals involving the Dirac delta function are evaluated directly by coordinate transformation, which yields more accurate results compared to applying numerical quadrature to an approximated delta function. Numerical results for ion and electron transport in solid electrolyte for lithium-ion (Li-ion) batteries are shown to be in good agreement with the experimental data and the results from previous studies. (Received September 17, 2013)

1096-65-2087 **Adrianna Gillman*** (adrianna.gillman@dartmouth.edu), **James Bremer** and **Per-Gunnar Martinsson**. *A high-order accurate accelerated direct solver for scattering from complicated 3D surfaces.*

Solving scattering problems involving complicated 3D surfaces to high accuracy is notoriously difficult. To do this efficiently is an even bigger challenge. In this talk, we present an accelerated direct solver that is coupled with high-order accurate quadrature to solve the corresponding integral equation. The direct solver handles the dense linear system via a two step process. First, a scattering matrix is precomputed for a computational cost that scales as $O(N^{1.5})$ where N is the number of discretization points. This matrix need only be computed once per geometry allowing additional sources charges to be handled for the cost of matrix-vector multiply. Typically, the size of the scattering matrix is much smaller than $N \times N$. For example, a $4 \times 4 \times 4$ grid of ellipsoids (each approximately one wavelength in size) requires 344,064 points on the surfaces of the ellipsoids to achieve 8 digits of accuracy while the scattering matrix size is only $1,377 \times 1,353$ and can be built in 93 minutes. For perspective, it took over 1000 GMRES iterations for the residual to fall below 10^{-3} when trying to solve a problem where the geometry consisted of a $2 \times 2 \times 2$ grid of ellipsoids each discretized with 1,536 points. (Received September 17, 2013)

1096-65-2091 **Sarah Jane Hamilton*** (sarah.hamilton@helsinki.fi), **Andreas Hauptmann** and **Samuli Siltanen**. *A Novel Data-Driven Edge Sharpening D-bar Reconstruction Algorithm for 2D Electrical Impedance Tomography.*

Electrical Impedance Tomography (EIT) is a non-invasive imaging modality that aims to recover the internal conductivity of a body via current and voltage measurements taken at its surface. The reconstruction task is a highly ill-posed nonlinear inverse problem, which is very 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 that solves the inverse conductivity problem uniquely. In many medical applications it is known a priori that the internal conductivity contains high-frequency features such as edges/jumps (i.e. at organ boundaries). In this talk, a novel approach of coupling this a priori knowledge with the D-bar method is introduced. The approach uses a functional representation for diffusive image segmentation, proposed by Ambrosio and Tortorelli, to sharpen and detect the boundaries of a blurred D-bar image. The resulting AT flow is controlled by the measured EIT data through a "CGO sinogram" at noise-robust scattering frequencies, providing a unique, stable, and highly effective reconstruction approach. Sharp reconstructions for discontinuous conductivities from noisy simulated EIT data are presented, suggesting this as an exciting new avenue for EIT. (Received September 17, 2013)

1096-65-2100 **Rachel A Ward*** (rward@math.utexas.edu), RLM, UT Austin, 2515 Speedway, Austin, TX 78712, and **Holger Rauhut**. *Interpolation via weighted l1 minimization.*

Functions of interest are often smooth and sparse in some sense, and both priors should be taken into account when interpolating sampled data. Classical linear interpolation methods are effective under strong regularity assumptions, but cannot incorporate nonlinear sparsity structure. At the same time, nonlinear methods such as l1 minimization can reconstruct sparse functions from very few samples, but do not necessarily encourage smoothness. Here we show that weighted l1 minimization effectively merges the two approaches, promoting both sparsity and smoothness in reconstruction. More precisely, we provide specific choices of weights in the l1 objective to achieve rates for functions with coefficient sequences in weighted lp spaces, p<=1. We consider the implications of these results for spherical harmonic and polynomial interpolation, in the univariate and multivariate setting. Along the way, we extend concepts from compressive sensing such as the restricted isometry property and null space property to accommodate weighted sparse expansions; these developments should be of independent interest in the study of structured sparse approximations and continuous-time compressive sensing problems. (Received September 17, 2013)

1096-65-2130 **James Brian Hall*** (j9hall@math.ucsd.edu), Department of Mathematics, University of California, San Diego (UCSD), 9500 Gilman Drive #0112, La Jolla, CA 92093-0112. *Long Term High-Order Numerical Integration with Galerkin Variational Integrators.*

Many standard methods of numerical integration are unsuitable for integration over long time periods. Symplectic integrators have been successful where standard methods have failed, and are often used for long term simulations. However, symplectic integrators are typically low order, and investigation of constructions of high order symplectic integrators is an area of active research. In this talk, I will present a method of constructing symplectic integrators of arbitrarily high order, and then demonstrate how these integrators can be efficiently implemented to facilitate very long term simulations. I will close with a numerical demonstration, a 100 million year integration of the Solar System using a very high order symplectic method. (Received September 17, 2013)

1096-65-2171 **Yu-Min Chung*** (yumchung@ku.edu), Snow Hall 405, 1460 Jayhawk Blvd, Lawrence, KS 66045, and **Ricardo Rosa** (rrosa@ufrj.br). *Inertial manifolds and foliations via Newton's method.*

Several Newton-type methods are presented for the accurate computation of the leaves in the foliation of an ODE near a hyperbolic fixed point. The foliation can be found through the Lyapunov-Perron method, which is an infinite dimensional problem. Hence, those methods are generalized to such cases. Local and global convergence results and the rate of convergence for those methods are investigated. The algorithms are demonstrated on a test problem and the Kuramoto-Sivashinsky equation. Finally, we compare these methods with the successive iteration method in terms of the algorithm complexity and efficiency. (Received September 17, 2013)

1096-65-2297 **Martin Gutting*** (gutting@mathematik.uni-siegen.de), University of Siegen, Emmy-Noether-Campus, Walter-Flex-Str. 3, 57068 Siegen, Germany. *Fast Multipole Accelerated Multiscale Analysis on the Sphere.*

Spherical wavelets allow a space-frequency decomposition of many geophysical quantities on the sphere allowing regional modeling or the improvement of a global model. Certain types of spherical wavelets allow the acceleration of the spherical convolution by the fast multipole method. The main idea of the fast multipole algorithm consists of a hierarchical decomposition of the computational domain into cubes and a kernel approximation for the more distant points. The direct kernel evaluation is performed only for points in neighboring cubes on the finest level. The contributions of the other points are taken into account by the kernel approximation.

Wavelet methods on the sphere come along with a tree algorithm that allows the computation of the lower frequency scales from a starting scale that contains the highest frequency parts of the signal. The application of the fast multipole method can accelerate the computation of this starting point as well as the tree algorithm itself.

Applications to gravitational field modeling and spherical denoising are presented and finally, the extension to boundary value problems is considered where the boundary is the known surface of the Earth itself. (Received September 17, 2013)

1096-65-2382 **Fernando Camacho*** (fercamacho@uky.edu) and **Alan Demlow**. *L_2 and pointwise error estimates for FEM for elliptic PDE on surfaces.*

We present a posteriori L_2 and pointwise error estimates for Surface Finite Element Methods for solving the Laplace-Beltrami equation over a C^3 surface Γ. We use and prove approximation properties for the Scott-Zhang interpolant which are valid for broken Sobolev norms, whereas the usual approximation results for Scott-Zhang type interpolants require globally defined Sobolev spaces. Our estimates contain a "classical" Galerkin component and a geometric component depending on Γ. Our studies indicate that the geometric component is of the same order as the Galerkin one and can dominate naturally defined adaptive algorithms. This contrasts with the corresponding a posteriori energy estimates where the geometric component decreases with a higher order than the Galerkin one. We present numerical experiments where the estimators have been used to implement an adaptive SFEM over surfaces with different curvatures. We refine our meshes using newest vertex bisection and observe the appearance of intermediate meshes Γ_h which contain elements that are not transverse to Γ. The existence of such local "kinks" in our mesh does not affect the convergence rates but does cause spikes in the geometric error and estimator as the mesh is refined. (Received September 17, 2013)

1096-65-2384 **Denis Ridzal**, **Stephen D. Shank*** (sshank@temple.edu), **Paul Tsuji** and **Ray Tuminaro**. *KKT preconditioners for non-Hermitian indefinite PDE systems.* Preliminary report.

We consider the numerical solution of linear systems arising in acoustic control. More specifically, we consider preconditioned iterative methods for solving KKT systems arising in PDE-constrained optimization where the underlying PDE is the time-harmonic wave equation in the frequency domain. An approach based on an approximation of the Schur complement is considered, with attention given to existing results for the case of a positive definite PDE operator and their extension to the indefinite case. As this approach requires repeated solves of the forward problem, we discuss the effect of a choosing a preconditioner that instead solves a damped problem. We focus on how this impacts the choice of solver for the forward problem and the overall consequences on solving the inverse problem. (Received September 17, 2013)

1096-65-2411 **Padmanabhan Seshaiyer*** (pseshaiy@gmu.edu), 4400 University Drive, MS 3F2, Exploratory Hall, Mathematical Sciences, George Mason University, Fairfax, VA 22030. *Quantitative modeling of biological and engineering systems through STEM problem solving activities.* Preliminary report.

In this talk, we will present the importance of quantitative modeling as a essential component of education reform across the curriculum in STEM. We will outline effective pedagogical approaches that can help to meaningfully include quantitative modeling, reasoning and analysis in understanding the mathematical relationships, the analysis of big data sets as well as the knowledge of useful computer simulations that provide useful insight into the data. Such important multi-disciplinary components will equip STEM majors with computational expertise sophisticated enough to generate quantitative predictions from models as well as improve their understanding of experimental techniques that can help them to understand important real-world questions. (Received September 17, 2013)

1096-65-2426 **M Zuhair Nashed*** (zuhair.nashed@ucf.edu). *Moment Discretization of Ill-Posed Problems.*

Moment problems arise in several areas of the geosciences. We consider such problems in the framework of ill-posed inverse problems and discuss some aspects of their regularization in the presence of strong noise and weakly bounded noise, based on joint work with Paul Eggermont. (Received September 17, 2013)

1096-65-2446 **Edriss S. Titi*** (etiti@math.uci.edu), Department of Computer Science & Applied Math, Weizmann Institute of Science, 76100 Rehovot, Israel. *Filtered turbulence models - rough variants of nonlinear Galerkin and post-processing Galerkin methods.*

In late 1990s we introduced, together with Garcia-Archilla and Novo, the *post-processing Galerkin method* (PPG) as an alternative to the nonlinear Galerkin method (NLG), where the latter was based on the theory of approximate inertial manifolds (AIM). The PPG is much cheaper to implement computationally than the NLG method, yet it possess the same rate of convergence (accuracy) as the simplest version of the NLG method; which is more accurate than the standard Galerkin method. Moreover, we will also show that the recently introduced *ad hoc* filtered models of turbulence are nothing other some rough, unjustifiable, variants of the NLG and PPG methods. (Received September 17, 2013)

1096-65-2528 **Abdramane Serme*** (aserme@bmcc.cuny.edu), 199 Chambers Street, New York, NY 10007, and **Jean W. Richard** (jrichard@bmcc.cuny.edu), 199 Chambers Street, New York, NY 10007. *Analyzing the Errors of an Extension of Wilkinson's Iterative Refinement or Improvement Algorithm.*

To find an accurate solution of an ill conditioned linear system $Ax = b$, we use the additive preconditioning $A \to C = A + UV^H$ for the preconditioner UV^H of a smaller rank r and the Schur aggregation technique to reduce the computation of $x = A^{-1}b$ to the computation of the Schur aggregate $S = I_r - V^H C^{-1} U$. The Schur aggregation is a process of transforming the linear system $Ax = b$ into better conditioned linear systems of smaller sizes, with well conditioned matrices $V^H C^{-1}$, $C^{-1}U$, S = Ir - VHC-1U using the Sherman-Morrison-Woodbury (SMW) formula $A^{-1} = (C - UV^H)^{-1} = C^{-1} + C^{-1}U(I_r - V^H C^{-1} U)^{-1} V^H C^{-1}$. We find S by computing $W = C^{-1}U$ using an extension of Wilkinson iterative refinement or improvement algorithm. Some steps of the algorithm are computed error free and other steps are computed with errors that need to be evaluated in order to determine the accuracy of the algorithm. In this presentation we will discuss the upper bound of the forward error of the algorithm to determine if its solution $W = C^{-1}U$ can be considered accurate enough. (Received September 17, 2013)

1096-65-2596 **Ana Maria Soane*** (asoane@towson.edu), Department of Mathematics, Towson University, 7800 York Road, Baltimore, MD 21252, and **Andrei Draganescu**. *Multigrid Preconditioners for Optimal Control Problems in Fluid Flow.* Preliminary report.

We consider the distributed optimal control problem associated with the tracking of the velocity/pressure of a Navier-Stokes flow in a bounded two-dimensional domain. The goal of our work is to construct multigrid preconditioners to accelerate the solution process. Our approach on previous work on the Stokes control problem was to eliminate the state and adjoint variables from the optimality system and to construct efficient preconditioners for the Schur-complement of the block associated with these variables. We extend this work to construct similar preconditioners for the reduced Hessian in the Newton-PCG method to be used for the numerical solution of the Navier-Stokes control problem. We show that for low to moderate Reynolds number the preconditioners display the same optimal behavior as in the case of the Stokes control problem. (Received September 17, 2013)

1096-65-2772 **Laurent Demanet*** (laurent@math.mit.edu). *Convex recovery from interferometric measurements*

Lifting, semidefinite relaxation, and expander graphs have recently helped formulate good solutions to the phase retrieval problem (Candes et al.) and the angular synchronization problem (Singer et al.) In this talk, I explain how the same line of thought reliably removes the local minima in interferometric inversion, a useful variant of numerical inverse scattering where the problem is to fit cross-correlations of wavefields rather than the wavefields themselves. While most compressed-sensing-like results assume randomness in the measurements, I explain why interferometric inversion is a setting in which a deterministic recovery result holds. In the process, we solve a question posed by Candes et al. in 2011 on robust phase retrieval. (Received October 02, 2013)

68 ► Computer science

1096-68-27 **Ivo D Dinov*** (dinov@stat.ucla.edu), 8125 Math Sciences, SOCR Resource, UCLA Statistics, Los Angeles, CA 90095, and **Arthur W Toga** (toga@loni.ucla.edu), Los Angeles, CA 90089. *Big Data Challenges in Neuroimaging, Informatics and Genomics Computing.*

The explosive growth in web-based storage, management, processing, and accessibility of biological and clinical data has been driven by our need for fundamental understanding of biological and physiological characteristics of disease processes. The enormous volume and complexity of biomedical data propel technological advancements realized as exponential increases in storage capability, processing power, and bandwidth capacity and transfer velocity. The rapid increases in data collection, computational processing, and statistical powering promote and facilitate collaborative, distributed team science and fuel the pace and volume of scientific discoveries, which ultimately advance our knowledge of diverse types of human health conditions and improve the efficacy of clinical interventions in disease diagnosis, treatment, and prevention. Despite it translational promise, Big Biomedical Data present significant challenges in handling, analyzing, and visualizing heterogeneous, incomplete, incongruent, and multi-scale data with little or no common data element standards, with or without Cloud service. We illustrate Big Data problems in the context of neuroimaging and genetics applications, and discuss Big Data discovery and analytics issues. (Received May 24, 2013)

1096-68-281 **Yifei Lou*** (louyifei@gmail.com), University of California Irvine, 340 Rowland Hall, Irvine, CA 92697, and **Ernie Esser**, **Hongkai Zhao** and **Jack Xin**. *Partially blind deblurring of barcode from out-of-focus blur.* Preliminary report.

This paper addresses the nonstationary out-of-focus (OOF) blur removal in the application of barcode reconstruction. We propose a partially blind deblurring method when partial knowledge of the clean barcode is available. In particular, we consider an image formation model based on geometrical optics, which involves the point-spread function (PSF) for the OOF blur. With the known information, we can estimate a low-dimensional representation of the PSF using the Levenberg-Marquardt algorithm. Once the PSF is obtained, the image deblurring is followed by quadratic programming. We find [0,1] box constraint is often good enough to enforce binary signal. Experiments on the real data demonstrate that the forward model is physically realistic and our partially blind deblurring method can yield good reconstructions. (Received August 26, 2013)

1096-68-283 **Sharareh Alipour*** (sharareh.alipour@gmail.com). *Approximation algorithm for the visibility counting problem using randomized method.*

For a set of n disjoint line segments S in R^2, the visibility counting problem,VCP, is to preprocess S such that the number of visible segments in S from a query point p can be computed quickly. This problem can be solved in logarithmic query time by using $\mathrm{O}(\mathrm{n}^4)$ preprocessing time and space.

Here, we approximately solve this problem using a randomized algorithm with tradeoff between space and query time. In the query time, we have 2 phases; In the first phase, we find the exact answer of VCP for the query which sees at most n^β of the segments and in the second phase, we approximate the number of visible segments for the query which sees more than n^β of the segments. The preprocessing time of our algorithm is $\mathrm{O}\epsilon(\mathrm{n}^{(4-3\beta)})$ and the query time is $\mathrm{O}\epsilon(\mathrm{n}^\beta)$ where $\mathrm{O}\epsilon(\mathrm{f(n)}) = \mathrm{O}(\mathrm{f(n)n}^\epsilon)$, which is prior compare to the best known algorithm for this problem.

To improve the approximation factor, we reduce the problem to a problem in graph theory. By using Euler formula we give a better approximation factor.

We also define the problem in R^3 and give applicable algorithms. For R^3 we present the experimental results too. (Received August 26, 2013)

1096-68-284 **Despina Stasi***, despina@psu.edu, and **Sonja Petrovic** and **Elizabeth Gross**. *Toric Geometry of Hypergraphs.*

Social networks and other large sparse date 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.

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. Our algorithm is based on the toric geometry of hypergraphs. The running example is the p_1 model for social networks, a statistical model of random directed graphs with reciprocation. (Received August 26, 2013)

1096-68-1000 **Erin Wolf Chambers*** (echambe5@slu.edu), Department of Math and Computer Science, 220 N. Grand Ave., St. Louis, MO 63103. *Topological measures of similarity for curves on surfaces.*

The question of how to measure similarity between curves in various settings has received much attention recently, motivated by applications in GIS data analysis, medical imaging, and computer graphics. While geometric measures such as the Hausdorff and Frechet distance have efficient algorithms, efficiently computable measures that take the underlying topology of the space are relatively new and unexplored. Several candidates have been proposed in recent years, but many of these are only tractable in restricted settings, and surprisingly little is known about their practicality. We will survey known results (both geometric and topological) in the first part of the talk, and then focus on new algorithmic results for the topological measures in the second half. The talk will conclude with open questions and possible new directions in this area. (Received September 12, 2013)

1096-68-1478 **Eunhui Park*** (eunhuipark@gmail.com), 6200 Westchester Park Dr. Apt 1502, College Park, MD 20740, and **David Mount**, College Park, MD 20740. *Output-Sensitive Well-Separated Pair Decompositions for Dynamic Point Sets.*

The well-separated pair decomposition (WSPD) is a fundamental structure in computational geometry. Given a set of n points in d-dimensional space and a positive parameter s, it is known that there exists an s-WSPD of size $O(s^d n)$. While this is linear in n, the factor of s^d is a significant consideration when the dimension d is even a moderately large constant. The actual number of pairs may be much smaller than this worst-case bound, for example, if the points are clustered near a lower dimensional subspace. Batch WSPD constructions are output sensitive, but existing algorithms for maintaining the WSPD of a dynamic point set are not. In this paper we present output-sensitive algorithms for maintaining the WSPD of a dynamic point set under insertion and deletion. (Received September 15, 2013)

1096-68-1517 **David White*** (dwhite03@wesleyan.edu), Wesleyan University Department of Mathematics, Exley Science Tower, Room 655, 265 Church Street, Middletown, CT 06457. *Traversals of Infinite Graphs with Random Local Orientations.*

In 1921 George Polya famously resolved the question of recurrence versus transience of the simple random walk on integer lattices. In this talk we will study the analogous question for random basic walks, which are random processes related to the problem of graph exploration by a mobile entity. After discussing recurrence results on other generalizations of simple random walks–en route introducing the notion of a random rotor router–we'll resolve the question for the random basic walk on lattices and then extend this result to a much larger class of graphs. If there is time at the end we'll return to the open problem on finite graphs from the paper which originally introduced the random basic walk. (Received September 16, 2013)

1096-68-1625 **Michael Mc Gettrick*** (michael.mcgettrick@nuigalway.ie), School of Mathematics, Statistics and, Applied Mathematics, National University of Ireland, Galway, Galway, Ireland, and **Colm O'Riordan**, **Jaroslaw Miszczak** and **Meng Li**. *Evolutionary quantum Prisoners Dilemma on the cycle graph C_n.* Preliminary report.

We generalize the iterated Prisoners Dilemma game, played on the cycle graph C_n, to its quantum version. We investigate the link between the structure of the graph and the resultant quantum states. For the most natural generalization, we calculate some quantum evolutionary stable strategies and show some novel properties of the iterated quantum game. (Received September 16, 2013)

1096-68-1973 **Diana Thomson La Corte*** (thomsond@uwm.edu), Department of Mathematical Sciences, EMS Building, Room E403, 3200 N Cramer Street, Milwaukee, WI 53211-3029. *The Newton's Method Backpropagation Algorithm for Holomorphic Complex-Valued Neural Networks.*

Complex-valued neural networks (CVNNs) offer distinct advantages over their real-valued counterparts in modeling real-world data. However, CVNNs pose unique problems. Real-valued activation functions for real-valued neural networks are commonly taken to be everywhere differentiable and bounded, but their complex counterparts cannot possess both desired properties at the same time. In particular, the complex-valued extensions possess poles in a bounded region near zero. We propose to use holomorphic functions as activation functions. In particular, we focus on entire functions, which do not possess poles and are bounded on bounded regions. Our approach allows us to develop the backpropagation algorithm for CVNNs using Newton's method and an adaptive algorithm to determine the learning rates and underrelaxation factors for the algorithm, which guarantees convergence to a local minimum and nonsingularity of the Hessian matrices at the iteration steps. We test the proposed algorithm on a typical classification problem to show the advantage of our approach. (Received September 16, 2013)

1096-68-2002 **Carola Wenk*** (cwenk@tulane.edu), Tulane University, Department of Computer Science, 6823 St. Charles Ave, New Orleans, LA 70118. *On map construction and map comparison.*

Map construction is a new type of geometric reconstruction problem in which the task is to extract the underlying geometric graph structure described by a set of movement-constrained trajectories, or in other words reconstruct a geometric domain that has been sampled with continuous curves that are subject to noise.

Due to the ubiquitous availability of geo-referenced trajectory data, the map construction task has widespread applications ranging from a variety of location-based services on street maps to the analysis of tracking data for hiking trail map generation or for studying social behavior in animals.

Several map construction algorithms have recently been proposed in the literature, however it remains a challenge to measure the quality of the reconstructed maps. We discuss incorporating uncertainty when modeling the input trajectories and the constructed maps. And we present different approaches to compare two such maps which amounts to comparing two uncertain embedded geometric graphs. (Received September 17, 2013)

1096-68-2188 **Noha El-Zehiry***, Siemens Corporation, Corporate Technology, 755 College Road East, Princeton, NJ 08540. *Combinatorial Optimization for PDE based Approaches to Computer Vision.*

Variational formulation methods have been widely used in the computer vision literature. They are used to solve a wide variety of problems such as image segmentation, denoising or registration. They generally establish an energy minimization framework where the minimum solution represents the object boundary in segmentation application, a denoised representation of the image or the desired correspondence between two images in registration applications. Most of these energies are formulated in continuous domain and associated with continuous gradient optimization. Such continuous formulations can be very slow to optimize and the optimization generally yield local solutions. An alternative strategy is to formulate these energies directly in the discrete domain and minimize the discrete energy functions using combinatorial optimization methods. This talk will present the discrete formulation of some of the important models in the computer vision literature such as the Mumford-Shah model and the Euler elastica regularization. It will also discuss the advantages of such discrete solutions and the optimization challenges associated with them. (Received September 17, 2013)

1096-68-2239 **Anastasios Sidiropoulos*** (sidiropo@gmail.com), CSE Dept., The Ohio State University, 589 Dreese Labs, 2015 Neil Av., Columbus, OH 43210. *L_1 embeddings of geometrically restricted planar graphs.*

The well-known planar embedding conjecture asserts that the shortest-path metric of every planar graph admits a constant-distortion embedding into L_1. This problem has received a lot of attention, and has important implications to the theory of multi-commodity network flows, and the design of approximation algorithms. So far, progress has been made only on topologically restricted planar graph classes, such as series-parallel, outerplanar [Gupta et al. '99], $O(1)$-outerplanar [Chekuri et al.'03], and $(K_5 \setminus e)$-free graphs [Chakrabarti et al. '08].

We discuss some of the limitations of current topological approaches, and present some recent progress on constant-distortion embeddings for geometrically restricted planar graphs. (Received September 17, 2013)

1096-68-2249 **John Ensley*** (john_ensley@brown.edu), **James Abello** and **Mika Sumida**. *My Life as a Tweet Word.*

Using selected topics of current interest on Twitter, we address the problem of visualizing an associated time varying graph for which data is being collected in a streaming fashion. We collect and analyze tweets relating to a common topic and display keywords in those tweets in a visually appealing manner. We use a novel edge decomposition of the associated graph ([1]). Nodes are assigned a value based on the Shannon's entropy of their adjacency degrees in the different layers of the decomposition. This value is used to determine the most "salient" words in the graph. Words appearing more consistently through time are displayed in a complementary "persistence diagram".

*This work was supported by the REU program at Rutgers University under the supervision of James Abello.

[1] J. Abello and F. Queroy, Fixed Points of Degree Peeling, Proceedings of ASONAM, Niagara Falls, August 2013. (Received September 17, 2013)

1096-68-2441 **Paul B Deignan*** (deignan@ada-vs.com), 8800 Sagebrush Trail, Aubrey, TX. *Information Theoretic Partition Determination for Data Mining.*

Association of descriptors to a set of target attributes is measured by an unbiased estimate of mutual information over a nonuniform partition. The algorithm of information-theoretic data association is shown to scale with O(N) dominated by a measure of significance of the estimate of entropic association. It is shown that the measure of statistical significance of the entropic estimates may also be used to bound the combinatorial search through multidimensional partitions thus allowing for the optimization of partition structure under the unbiased entropic measure of data association. (Received September 17, 2013)

1096-68-2686 **Michael McKerns*** (mmckerns@caltech.edu), 1200 E. California Blvd. MC158-79, Pasadena, CA 91125, and **Tim Sullivan**, **Clint Scovel** and **Houman Owhadi**. *mystic: a framework for high-dimensional nonlinear constrained optimization.* Preliminary report.

We have built a framework (mystic) for solving high-dimensional non-convex optimization problems with highly nonlinear constraints. Mystic is capable of solving global optimization problems with thousands of parameters and thousands of constraints, and can leverage high-performance parallel computing. Mystic's unique ability to apply statistical constraints can be used to calculate risk, uncertainty, and probability of failure in real-world inverse problems. Typically, termination conditions and initial conditions are hard-coded into an optimization algorithm - however, in mystic, conditionals are dynamically configurable, and thus facilitate optimizer tuning to solve a much broader range of problems. Mystic provides box constraints, penalty functions, and a constraints toolkit inspired by set theory that applies constraints as operators. With the ability to scale up to thousands of parameters, mystic can solve optimization problems that are orders of magnitude larger and of greater complexity than conventional solvers are capable of. Mystic has been used in materials failure under hypervelocity impact, elasto-plastic failure in structures under seismic ground acceleration, and structure prediction in nanomaterials. Mystic is available at http://pythonhosted.org/mystic. (Received September 17, 2013)

1096-68-2717 **Ahlam E Tannouri*** (ahlam.tannouri@morgan.edu), Mathematics Department, Morgan State University, 1700 E. Cold Spring, Baltimore, MD 21251, and **Sam F Tannouri** (sam.tannouri@morgan.edu), Computer Science Department, Morgan State University, 1700 E.Cold Spring, Baltimore, MD 21251. *Exploration of Flocking Clustering Algorithms for Information Display and Derivation of Structures in Big Data.* Preliminary report.

Flocking Clustering Algorithms can be used in the exploration of big data sets pertaining to social interactions. The uncovering of underlying structures, the identification of unusual patterns and the detection of possible outliers can have major implications for planning evacuations in case of major disasters. Interactive visualization techniques will be presented with sets of synthetic data deriving several structures and highlighting the flock behavior like in humans.

Sponsored By CCICADA The Command, Control,and Interoperability Center for Advanced Data Analysis. (Received September 18, 2013)

70 ► Mechanics of particles and systems

1096-70-600 **Rajinder Singh Mavi***, rsm8y@virginia.edu, and **Svetlana Jitomirskaya**. *Upper bounds on quantum dynamics for quasiperiodic Schrödinger operators with rough potentials.*

Delocalization in quantum systems is forced by (fractal) continuity of the spectral measure of the Hamiltonian, but the converse is not as complete as only partial dynamical localization can be enforced by fractal singularity of the spectrum. General conditions for upper bounds on quantum dynamics have been developed by various authors, notably by Killip, Kiselev and Last and Damanik and Tcheremchantsev. These authors also apply these results to the quasiperiodic Schrödinger equations with discrete and trigonometric potentials. As with most studies of the quasiperiodic Schrödinger operator, there are no complete results for rough potentials. Our focus in this talk is to discuss the situation for the rough potential as relates to dynamics and present results for partial and total dynamical localization. This talk covers joint work with Svetlana Jitomirskaya. (Received September 07, 2013)

1096-70-2512 **Nebojsa Murisic*** (nmurisic@princeton.edu), Lewis-Sigler Institute, for Integrative Genomics, Princeton University, Princeton, NJ 08544, **Basile Audoly** (audoly@lmm.jussieu.fr), CNRS and, Institut de mecanique d'Alembert, Place Jussieu, 75252 Paris, Cedex 05, France, **Yannis G. Kevrekidis** (yannis@arnold.princeton.edu), Chemical and Biological Engineering, Princeton University, Princeton, NJ 08544, and **Stanislav Y. Shvartsman** (stas@princeton.edu), Lewis-Sigler Institute, for Integrative Genomics, Princeton University, Princeton, NJ 08544. *Buckling in vertex models of epithelial sheets.*

Recent studies of Drosophila (fruit fly) show that buckling plays a critical role in development of eggshell respiratory tubes. Cells within a 2D epithelial sheet locally secrete motor protein myosin giving rise to in-plane embedded stress. Complex 3D structures result. We consider a simplified system where the epithelium is represented by a 2D axisymmetric sheet of hexagonal cells. Our vertex model accounts for cell-cell adhesion and tissue elasticity. We study buckling in this discrete model. We calculate equilibrium shapes under stress and study their stability. We show that a 2D sheet subjected to embedded closed line compressive cable undergoes a buckling transition: a flat solution loses stability giving rise to a pair of stable 3D solutions. A supercritical pitchfork bifurcation results, typical to buckling in the continuum elasticity theory. The influence of material and geometrical parameters is also studied. We employ asymptotics to derive effective bending and stretching moduli, the balance of which determines the buckling threshold. A continuum system equivalent to our discrete setup is also derived. We provide a novel way to study buckling in biological systems, allowing for a high level of biological realism and computational tractability. (Received September 17, 2013)

74 ► Mechanics of deformable solids

1096-74-868 **Alla V Balueva*** (alla.balueva@ung.edu), University of North Georgia, Mathematics Department, P.O. Box 1358, Gainesville, GA 30503. *Analytical Estimates for Pipe-lines Longevity.*

While estimating longevity of pipelines transporting oil and gas, it is necessary to take into account the presence of small cracks in the metal, which can be later the reason of a sudden rupture of pipelines. In addition, hydrogen diffuses into the metal of the pipelines and accumulates inside the cracks. The growth of hydrogen induced cracks is controlled by the gas diffusion. Two mixed Dirichlet-Neumann boundary value problems of elasticity theory and diffusion theory with the crack contour as a boundary for the boundary conditions are reduced to two integral equations. For sake of simplicity, we consider a penny-shaped crack, which gives an axi-symmetrical problem. The two problems then are connected through the real gas equation of state. After reducing the problem to the integral equation for the crack radius, it is possible in the steady state case to obtain a closed-form solution of how the crack radius grows with time. The results show that depending on the different external factors such as the initial gas concentration or properties of the metal, the time until the crack radius reaches a critical value (a fatal fracture) is different, changing from several days to thousands of years, which gives recommendations as to when certain parts of pipelines should be replaced. (Received September 12, 2013)

1096-74-912 **Guillermo H Goldsztein*** (ggold@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, 686 Cherry Street, Atlanta, GA 30332-0160. *Ideally plastic composites.*

We consider fiber reinforced composites where both the matrix and the fibers are ideally plastic materials. We restrict our attention to microstructures and applied stresses that lead to both microscopic and macroscopic antiplane shear deformations. We discuss a bound on the yield set of the composite in terms of the shape of the fibers, their volume fraction, and the yield set of the matrix. We construct examples of composites showing that this bound is essentially optimal. (Received September 11, 2013)

1096-74-2493 **Timothy Blass**, **Irene Fonseca**, **Giovanni Leoni** and **Marco Morandotti*** (marco.morandotti@ist.utl.pt), Departamento de Matemática, Av. Rovisco Pais, 1, 1049-001 Lisboa, Portugal. *Dynamics for a System of Screw Dislocations.* Preliminary report.

Dislocations are defects in solid crystalline structures that are characterized by their Burgers vectors, which describe the lattice mismatch. The interest in their study lies in the influence that their presence has on the properties of the material itself.

We describe the energy and the dynamics for a system of screw dislocations subject to anti-plane shear. A variational setup is constructed to find minimizers for the energy functional associated with a system of screw dislocations in an elastic medium. By taking the spatial derivative of the energy in the equilibrium configuration, it is possible to write a system of ordinary differential equations that govern the motion of the dislocations in the material. This model for the dynamics is due to Cermelli and Gurtin.

We rely on standard variational techniques for achieving the results in the first part, whereas a weak notion of solutions (in the sense of Filippov) to ordinary differential equations has to be invoked to solve the dynamics problem. (Received September 17, 2013)

76 ► Fluid mechanics

1096-76-235 **Devinder Singh Bittoo*** (despathanai@yahoo.com), Department of Mathematics, Guru Nanak Dev Engg. College, Gill Road Ludhiana,Punjab India, Ludhiana, India. *Propagation of Waves in Homogeneous Isotropic Plates.*

In this paper the propagation of thermo elastic waves in homogeneous isotropic plate subjected to free and rigid insulated and isothermal conditions is investigated in the context of conventional coupled thermoelasticity, Lord Shulman, Green –Lindsay and Green-Nagadhi theories of thermoelasticity. Secular equations for the plate in the closed form and isolated mathematical conditions for symmetric and skew symmetric wave mode propagation in completely separate terms are derived. It is observed that the motion for SH modes get decoupled from rest of the motion and remains unaffected due to thermo-mechanical coupling and thermal relaxation effects. The results for coupled and uncoupled theories of thermo elasticity have been obtained as particular cases from the derived secular equations. At short wavelength limits the secular for symmetric and skew symmetric waves in stress free insulated and isothermal plate reduce to Rayleigh surface frequency equations. The results obtained have been verified numerically for aluminum-epoxy composite material and dispersion curve for symmetric and skew-symmetric wave modes are presented to illustrate and compare the theoretical result. (Received August 21, 2013)

1096-76-482 **Alexey Cheskidov** (acheskid@uic.edu), University of Illinois at Chicago, MSCS (M/C 249), 851 South Morgan Street, Chicago, IL 60607, and **Karen Zaya*** (kzaya2@uic.edu), University of Illinois at Chicago, MSCS (M/C 249), 851 South Morgan Street, Chicago, IL 60607. *Regularizing Effect of the Forward Energy Cascade in the Inviscid Dyadic Model.*

We study the inviscid dyadic model of the Euler equations and prove some regularizing properties of the nonlinear term that occur due to forward energy cascade. This leads to several regularity results the inviscid case. We conjecture that every blow up has Onsager's scaling and discuss recent progress toward achieving this goal. (Received September 12, 2013)

1096-76-618 **Vladimir A Chugunov** (vladimir.chugunov@kpfu.ru), Institute of Mathematics and Mechanics, Kazan Federal University, Kazan, 420008, Russia, **Sergei A Fomin*** (sfomin@csuchico.edu), Department of Mathematics and Statistics, CSU Chico, Chico, CA 95929, and **Ravi Shankar** (ravdogster@gmail.com), Department of Chemistry, UC Davis, Davis, CA. *Tsunami wave propagation over underwater obstacles and steps.*

Solitary wave propagation over underwater shelves and bumps is examined using straightforward analytical methods. Explicit solutions for wave propagation are obtained. The effects of topographical variety and proportion (steps, bumps, obstacles) on the incident wave are demonstrated using linear wave theory. At a step, the incident wave is shown to be more strongly reflected for increased barrier size. The incident wave also transmits an amplified wave with smaller wavelength onto the obstacle. After propagating off of a bump, the wave experiences an amplitude decay. The decay rate is shown to be exponential with a variable number of bumps. Over an infinitely long shelf, the amplified transmitted wave breaks. The time at which the wave breaks is predicted with weakly nonlinear wave theory and favorably validated against fully nonlinear numerical simulations. (Received September 08, 2013)

1096-76-621 **Nathaniel Karst*** (nkarst@babson.edu), **Brian Storey** and **John Geddes**. *Spontaneous oscillations in simple fluid networks.*

Nonlinear phenomena including multiple equilibria and spontaneous oscillations are common in fluid networks containing either multiple phases or constituent flows. In many systems, such behavior might be attributed to the complicated geometry of the network, the complex rheology of the constituent fluids, or, in the case of microvascular blood flow, biological control. In this paper we investigate two examples of a simple three-node fluid network containing two miscible Newtonian fluids of differing viscosities, the first modeling microvascular blood flow and the second modeling stratified laminar flow. We use a combination of analytic and numerical techniques to identify and track saddle-node and Hopf bifurcations through the large parameter space. In both models, we document sustained spontaneous oscillations and, for an experimentally relevant example of parameter analysis, investigate the sensitivity of these oscillations to changes in the viscosity contrast between the constituent fluids and the inlet flow rates. For the case of stratified laminar flow, we detail a physically realizable set of network parameters that exhibit rich dynamics. The tools and results developed here are general and could be applied to other physical systems. (Received September 08, 2013)

1096-76-634 **Dambaru Bhatta*** (bhattad@utpa.edu). *Three dimensional hydro-thermal convective flow in an aquifer system.* Preliminary report.

Abstract Here we consider a three dimensional hydro-thermal convective flow in an aquifer system. We assume that the aquifer is heated from below, and it is bounded below and above by impermeable boundaries. The partial differential equations governing the system are conservation of mass, conservation of heat and momentum equation governed by the Darcy's law. Using basic state solutions and the critical pair of Rayleigh number and wavenumber, the linear and adjoint systems for three dimensional case are obtained. Then we derive the Landau equation for the amplitude of this flow. Analytical expression as well as numerical values for the Landau constant are presented. (Received September 08, 2013)

1096-76-698 **Sarthok Sircar*** (sircar1981@gmail.com), 1350 and 20th Street, Apartment J24, Boulder, CO 80302. *Chemotactic adhesion is bacterial flocs: a multi-scale model.*

Most of today's experimentally verifiable scientific research, not only requires us to resolve the physical features over several spatial and temporal scales but also demand suitable techniques to bridge the information over these scales.

In this talk, I present numerical results of the adhesion fragmentation dynamics of bacteria (or in general: rigid, round particles) clusters subject to a homogeneous shear flow. In the continuum level we describe the dynamics of the number density of these cluster. The description in the micro-scale includes (a) binding/unbinding of the bonds attached on the particle surface, (b) bond torsion, (c) surface potential due to ionic medium, and (d) flow hydrodynamics due to shear flow.

Results show certain features in the adhesion dynamics which were not captured experimentally. (Received September 09, 2013)

1096-76-711 **Shuwang Li***, Engineering One Bldg, Room 208, 10 West 32nd Street, Applied Math Dept. IIT, Chicago, IL 60616, and **Meng Zhao**, **Andrew Belmonte** and **John Lowengrub**. *A curvature weakening Hele-Shaw model.*

In this talk, we present a model of Hele-Shaw flow in which two immiscible fluids react and produce a gel-like phase at the interface. Since the gel-phase can make the interface stiff, we model the interface as an elastic membrane whose bending stiffness depends on the local curvature. We show linear stability analysis and preliminary numerical results on fingering instability in such as system. (Received September 09, 2013)

1096-76-771 **Anna L Mazzucato*** (alm24@psu.edu). *Vorticity concentration at the boundary for Taylor-Couette flows in the zero viscosity limit.*

I will present rigorous results concerning vorticity concentration at the boundary as a vortex sheet in the limit of vanishing viscosity for certain types of Taylor-Couette flows in pipes and channels. This is joint work with several authors. (Received September 10, 2013)

1096-76-825 **Roger M Temam***, Indiana University, Mathematics Department, Rawles Hall, 831 E 3rd Street, Bloomington, IN 47405, and **Michele Coti Zelati**. *Change of phase for the humid atmosphere.*

In this lecture we will recall the atmospheric equations of water vapor with saturation. In their simplest form, these equations form a nonlinear system of partial differential equations with discontinuities. We will address the issues of the definition of the solutions, and some questions on the existence, uniqueness and regularity of these solutions. (Received September 10, 2013)

1096-76-1237 **Daniel M Anderson*** (danders1@gmu.edu), Dept. of Mathematical Sciences, 4400 University Drive, MS3F2, George Mason University, Fairfax, VA 22030. *Homogenization for Free Boundary Problems in Layered Porous Media.*

We examine mathematical models and homogenization approaches for gravity currents in heterogeneous porous media. We first outline the dynamics of a gravity current in a layered porous media slumping along an impermeable bottom boundary. We then focus on a simpler geometry in which a free-boundary problem characterizes one-dimensional drainage through layered media. We examine analytical and numerical solutions as well as ones generated by asymptotic approximation schemes. Of particular interest is the identification of corrections to the leading-order approximations based on homogenization theory. (Received September 13, 2013)

1096-76-1249 **Mohammad Salim Zannon*** (zanno1ms@cmich.edu), Department Of Mathematics, Central Michigan University, Mount Pleasant, MI 48859, and **Mohamad S. Qatu** and **Leela Rakesh**. *Free Vibration Analysis of Thick Cylindrical Composite Shells Using Higher Order Shear Deformation Theory.*

This paper presents the free vibration analyses of laminated cylindrical shells using higher order shear deformation theory. Equilibrium equations are used from the mathematical formulations of stress resultants and strain displacement from our previous work [Zannon et al.2012] and are then solved for free vibrations. Such analog gives us various lumped frequencies, if any present, in the system using different boundary conditions, and various thickness and depth ratios present in the thick cylindrical composite shells. For the present formulations the boundary conditions considered are simply supported lamination cross ply. Here, we specifically developed mathematical equations by considering transverse normal stress, shear deformation and rotary inertia in the shell system. The governing equations of motion are expressed in terms of eight kinematic equations using the constitutive and kinematic relationships based on the theory of elasticity. The free vibrational analysis using the third -order shear deformation shell theory leads to a system of generalized eigenvalue problem, which then numerically solved using MATLAB. The first five natural frequency parameters are reported and compared with previously published research (first order approximation and 3D finite element). (Received September 13, 2013)

1096-76-1571 **Aseel Farhat***, 831 E 3rd St, Mathematics Department, Bloomington, IN 47405, and **Michael Jolly** and **Evelyn Lunasin**. *Bounds on energy and enstrophy for the 3D Navier-Stokes-α and Leray-α models.*

We construct semi-integral curves which bound the projections of the global attractors of the 3D NS-α and 3D Leray-α sub-grid scale turbulence models in the plane spanned by their energy and enstrophy. We note the dependence of these bounds on the filter width parameter α, and determine subregions where each quantity, energy and enstrophy, must decrease, while isolating one which is recurrent. (Received September 16, 2013)

1096-76-1583 **Emmanuel Grenier*** (emmanuel.grenier@ens-lyon.fr), UMPA, Ecole Normale Supérieure de Lyon, 46 allée d'Italie, Lyon, France. *New advances in boundary layers for Navier Stokes equations.*

The question of existence and stability of boundary layers in the inviscid regime of Navier Stokes equations is a classical problem in Fluid dynamics.

Formally, so called Prandtl boundary layers appear. However for some range of parameters they are known to be unstable.

In this talk we will review recent progress in the mathematical study of these instability.

Work in collaboration with T. Nguyen and Y. Guo (Brown University) (Received September 16, 2013)

1096-76-1670 **Muhammad Hameed*** (mhameed@uscupstate.edu), University of South Carolina Upstate, 800 University Way, Spartranburg, SC 29303. *Singularity approach to study the particle encapsulation in a liquid thread.*

The capillary instability of a viscous liquid thread containing solid particles is studied. The solid spherical particle is placed at the center-line of the liquid column. The liquid is highly viscous and the governing equations are axi-symmetric Stokes equations. The presence of the force-free particle is represented by a symmetric hydrodynamic force dipole. A simplified long-wave mathematical model is derived and numerical simulations are carried out to study different aspects of trapped solid particles in thread elongation. Results are presented for one solid particle, different particle sizes and for multiple particles symmetrically placed along the center-line. (Received September 16, 2013)

1096-76-1771 **Lauren R. Johnson*** (lrjohns7@asu.edu), 3031 E. Bighorn Ave., Phoenix, AZ 85048, and **Lee M. Burke**, **Chris Barton** and **Mohamed Moustaoui**. *Stability and accuracy analysis for a novel semi-implicit leapfrog time-stepping scheme.*

A new time stepping scheme is proposed. It is based on the semi-implicit method and the leapfrog method with a fourth-order time filter. The scheme is implicit and requires only one evaluation per time step. We test the order and stability of the scheme by applying it to the wave equation. Comparisons are made with the standard Robert-Asselin filtered leapfrog scheme and with the explicit leapfrog scheme with a fourth-order time filter, using filter coefficients that damp the computational $2\Delta t$ modes at the same rate. We will show that the proposed scheme improves the resolution of the physical modes, increases the zone of stability compared to the traditional time-filtered leapfrog schemes, and damps the computational modes. This new method is an attractive candidate for atmospheric, oceanic, and climate modeling. (Received September 16, 2013)

1096-76-1889 **W. Brent Lindquist*** (blindquist@stonybrook.edu), Applied Mathematics and Statistics, Stony Brook University, Stony Brook, NY 11794-3600, and **Daesang Kim** (daesang.kim@kaust.edu.sa), Clean Combustion Research Center, KAIST, Thuwal, 23955-6900, Saudi Arabia. *Up-scaling Reaction Rates from Pore to Core Scale.*

Effective up-scaling requires identifying key information that must be transmitted from smaller to larger length scales. We examine this issue in the context of predicting reaction rates in flow through geologic media. We focus on up-scaling, from pore to core scale, of rates of anorthite and kaolinite reaction in sandstone under acidic condition. Due to inherent heterogeneities in rock structure, mineral placement, fluid velocity, and geometric changes induced by reaction, core-scale reaction rates differ significantly from the microscopic rate laws. Core up-scaled reaction rates were computed using network flow models. The simulations captured the time development of bulk reaction rates and allowed investigation of uncertainties in our knowledge of micro-scale reaction rates, as well as dependence of bulk reaction rates on flow rate. For the far-from-equilibrium reaction, our results indicate that the ability to correctly capture the heterogeneity in dissolution changes in the reactive mineral surface area is critical to accurately predict up-scaled reaction rates. For the near-equilibrium reaction, the ability to correctly capture the heterogeneity in the saturation state remains critical. (Received September 16, 2013)

1096-76-1904 **Gautam Iyer***, Dept. of Math-Sci, Carnegie Mellon University, Pittsburgh, PA 15206, and **Alexei Novikov** and **Lenya Ryzhik**. *Anomalous diffusion of tracer particles in fast cellular flows.*

It is well known that a diffusive tracer particle in the presence of an array of strong opposing vortices (aka cellular flow) behaves like an effective Brownian motion on long time scales. On intermediate time scales, however, a robust anomalous diffusive behaviour has been numerically observed. This talk is a first step towards understanding this anomalous behaviour. We will show that the variance of the particle behaves like $O(\sqrt{t})$ on "intermediate" time scales; in contrast, the long time behaviour of the variance is like $O(t)$. (Received September 16, 2013)

1096-76-1913 **Gautam Iyer***, Dept. of Math-Sci, Carnegie Mellon University, Pittsburgh, PA 15206, and **Alexander Kiselev** and **Xiaoqian Xu**. *Lower bounds on the mix norm of passive scalars advected by incompressible enstrophy-constrained flows.*

Consider an diffusion-free passive scalar θ being mixed by an incompressible flow u on the torus $\mathbb{T}^d$. Our aim is to study how well this scalar can be mixed under an enstrophy constraint on the advecting velocity field. Our main result shows that the mix-norm ($\|\theta(t)\|_{H^{-d/2}}$) is bounded below by an exponential function of time. The exponential decay rate is morally the measure of the support of the initial data, and agrees with both physical intuition and numerical simulations. The main idea behind our proof is to use the notion of "mixed to scale δ" and recent work of Crippa and DeLellis towards the proof of Bressan's rearrangement cost conjecture. (Received September 16, 2013)

1096-76-1941 **Matthew Glomski***, School of Computer Science and Mathematics, Marist College, 3399 North Road, Poughkeepsie, NY 12601, and **Matthew A. Johnson**. *Interval analysis computation of the critical Rayleigh number for the asymmetric Rayleigh-Bénard problem.*

The critical Rayleigh number $\mathcal{R}_c$ arises as a threshold constant in the Rayleigh-Bénard problem of classical fluid dynamics. In 1916, Lord Rayleigh found an exact expression for $\mathcal{R}_c$ in the no-stress, or *free-free*, boundary formulation of the problem. In 1999, Jeng and Hassard gave an error-bounded fifty-decimal computation for the constant in the no-slip *rigid-rigid* case. In this talk, we will discuss interval methods used in the first error-bounded computation of the Rayleigh number for the asymmetric *rigid-free* formulation of the problem. (Received September 16, 2013)

1096-76-1956 **Yue Yu*** (yue_yu_1@brown.edu), Box.f 182 george st, providence, RI 02912, and **Johnny Guzman** and **George Karniadakis**. *A penalty method for coupling fluid-structure interactions.*

In this work, we develop a new stabilized explicit coupling partitioned scheme or the fluid-structure interaction problem, to the case where the pressure and velocity are decoupled, i.e. the fluid part is solved with projection methods. Specifically, proper penalty terms are applied on the displacement, pressure and velocity solvers separately, to control the variations at the interface. Using energy stability analysis, it can be shown that the scheme is stable independent of the fluid-structure density ratio. All the implementations are done with the spectral element method as explained in [Yu et al, 2013]. Numerical examples are provided to show that although the penalty terms will degrade the time accuracy of the scheme by half order, optimal accuracy can be recovered by performing defect-correction subiterations. (Received September 16, 2013)

1096-76-1983 **Zachary Bradshaw** and **Zoran Grujic*** (zg7c@virginia.edu). *Turbulent transport in 3D incompressible plasma.*

The goal of this talk is to present a mathematical framework for rigorous study of turbulent transport in 3D incompressible plasma in physical space/scales of the flow. The range of scales in view extends from a relevant macro-scale down to the scale of proton gyro-radius (the fluid/continuum realm), and the method is based on a suitable dynamic multi-scale ensemble averaging of the local dynamics described by the full 3D MHD system. The method is illustrated with several rigorous results on turbulent transport both on the energy and enstrophy levels. (Received September 17, 2013)

1096-76-1997 **Lee M. Burke*** (lmburke2@asu.edu), 2 W. Erie Dr., Tempe, AZ 85282, and **Lauren R. Johnson**, **Chris Barton** and **Mohamed Moustaoui**. *A new numerical scheme based on the leapfrog method for atmospheric and ocean modeling.*

A semi-implicit, fourth-order time-filtered leapfrog numerical scheme is presented and applied to the global shallow water spectral model to simulate the nonlinear evolution of twin tropical cyclones. This is a challenging model problem to illustrate the efficacy of a novel time-filter for the leapfrog scheme. The leapfrog scheme leads to computational modes in the solutions to highly nonlinear systems, and time-filters are often used to damp these modes. The proposed filter damps the computational modes without degrading the physical mode. This scheme is third-order accurate in amplitude and has a larger zone of stability compared to the standard Robert-Asselin filtered leapfrog scheme, which is first-order accurate. This talk presents the new time-stepping scheme, demonstrates its ability to suppress the computational modes, and shows its applicability and implementation in a global spectral atmospheric model. (Received September 17, 2013)

1096-76-2044 **Ciprian Foias**, **Michael S Jolly*** (msjolly@indiana.edu), **Ruomeng Lan**, **Rishika Rupam**, **Yong Yang** and **Bingsheng Zhang**. *Time analyticity with higher norm estimates for the 2D Navier-Stokes equations.*

We present bounds on norms of all orders for solutions on the global attractor $\mathcal{A}$ of the 2D Navier-Stokes equations, complexified in time. Specifically, for periodic boundary conditions on $\Omega = [0, L]^2$, and a force $g \in \mathcal{D}(A^{\frac{\alpha-1}{2}})$, we show there is a fixed strip about the real time axis on which a uniform bound $|A^\alpha u| < m_\alpha \nu \kappa_0^\alpha$ holds for each $\alpha \in \mathbb{N}$. Here A is the Stokes operator, ν is viscosity, $\kappa_0 = 2\pi/L$, and m_α is explicitly given in terms of g and α. We show that if any element in $\mathcal{A}$ is in $\mathcal{D}(A^\alpha)$, then all of $\mathcal{A}$ is in $\mathcal{D}(A^\alpha)$, and likewise with $\mathcal{D}(A^\alpha)$ replaced by $C^\infty(\Omega)$. We demonstrate the universality of this "all for one, one for all" law on the union of a hierarchal set of function classes. Finally, we treat the question of whether the zero solution can be in the global attractor for a nonzero force by showing that if this is so, the force must be in a particular function class. (Received September 17, 2013)

1096-76-2176 **Nicholas Gewecke*** (ngewecke@math.udel.edu), **Rich Braun**, **Chris Breward** and **P. Ewen King-Smith**. *Two Layer Model for Tear Film Dynamics.* Preliminary report.

Many tear film models utilize a single layer, while some recent models include surfactant effects at the liquid-air interface to model the effects of polar lipids. Clinical observations indicate more complicated dynamics of the lipid layer than demonstrated by these previous models, such as the formation of lipid drops, but the dynamics are not well-understood. Our model includes a very thin viscous layer representing the nonpolar lipid layer between the aqueous layer and the air, to capture some of these dynamics and to aid in understanding the mechanisms behind these dynamics. (Received September 17, 2013)

1096-76-2309 **Jean-Luc Guemond**, **Adam Larios*** (alarios@math.tamu.edu) and **Travis Thompson**. *Turbulence Modeling via Entropy Functionals.*

The entropy-viscosity technique is a new class of high-order numerical methods for approximating scalar conservation laws which have recently been adapted as a numerical regularization for the Navier-Stokes equations. A nonlinear, LES-type viscosity is based on the numerical entropy residual, causing the numerical dissipation to become large in the regions of (numerical) shock, and small in the regions where the solution remains smooth. I will discuss this method as a numerical regularization for the Navier-Stokes equations, along with related regularizations and applications to other equations if time permits. (Received September 17, 2013)

1096-76-2395 **Shilpa Khatri***, khatri@email.unc.edu, and **Roberto Camassa**, **Claudia Falcon**, **Richard McLaughlin**, **Jennifer Prairie**, **Brian White** and **Sungduk Yu**. *Settling of a Porous Particle in Stratified Flow.*

Marine snow, porous aggregates composed of phytoplankton, fecal pellets, sediment, detritus and other material found in the ocean, are fundamental to the carbon flux from the surface ocean to the deep ocean. Most of these macroscopic particles are extremely porous, allowing diffusion of a stratifying agent (heat or salt) from the ambient fluid to affect the density and therefore the settling dynamics of these particles. A first step in an ongoing investigation is to study the settling of a single porous particle through ambient density gradients, focusing on effects of porosity and salt diffusion. For linear stratification in viscosity dominated regimes, an explicit solution for the sphere's position in time is derived. For more general ambient fluid stratification, the sphere's position can be solved for numerically. A discussion about the competing effects of entrainment and diffusion will be included. A parametric study of the settling behaviors and comparisons with experiments will be presented. (Received September 17, 2013)

1096-76-2496 **Joanna A Bieri*** (joanna_bieri@redlands.edu). *Computational Modeling of the Dynamics of Edge Flames in Narrow Channels.* Preliminary report.

Edge flames are fundamental two dimensional structures that appear in the burning of non-premixed flames in narrow channels. Experimental work has shown a surprising range of behaviors for these flames including oscillations along the length of the narrow channel and flame extinction-reignition patterns. This work models the edge flame in a narrow channel as a reacting two dimensional flow of fuel and oxidizer. Under the diffusive-thermal assumption, this leads to a coupled system of three nonlinear partial differential equations for the flame, which are solved numerically. When we remove the thermal-diffusive assumption, allowing for density variations, the flame equations are coupled with the underlying fluid flow. The full steady state equations are solved numerically to determine the effects of thermal expansion. We consider both symmetric and non-symmetric flames along with conditions for the combustor walls ranging from adiabatic to heat conduction. The goal of this work is to better understand flame oscillations, extinction, and reignition. (Received September 17, 2013)

1096-76-2641 **Loren Cobb*** (loren.cobb@ucdenver.edu), Dept of Mathematics, University of Colorado Denver, **Lynn Bennethum** (lynn.bennethum@ucdenver.edu), Dept of Mathematics, University of Colorado Denver, and **Mark Mueller** (mark.mueller@ucdenver.edu), Dept of Mathematics, University of Colorado Denver. *Modeling Refugee Flow with the Continuum Mechanics of Porous Media.* Preliminary report.

Recent developments in the continuum mechanics methods for multiphase and multicomponent porous media offer some unexpected benefits for modeling the flow of refugees during complex humanitarian emergencies. We develop the appropriate conservation and constitutive equations in the context of intense ethnic conflict, and show how these equations generate plausible mass refugee movements under the influence of two scalar fields: perceived threat, and terrain conditions. Finally, we show how both the Eulerian and Lagrangian views translate into radically different but complementary computational social simulation strategies. This research was supported by NSF grant DMS-1216481. (Received September 17, 2013)

78 ► Optics, electromagnetic theory

1096-78-1298 **Pengrui Hui*** (hpengrui11@students.desu.edu). *Moving Window Finite-Difference Time-Domain Method with Perfectly Matched Layer Boundary Conditions.*

In this work, we study the moving window Finite-Difference Time-Domain (FDTD) method with the Perfectly Matched Layer (PML) absorbing boundary condition for solving Maxwell's equations of electromagnetic waves over a long-distance region. The FDTD method is widely used in solving Maxwell's equations numerically. When dealing with the long-distance wave propagation, the computational burden quickly becomes too huge to afford. To overcome this problem, we investigate the moving window or moving frame technique. In this thesis, we focus on the Eulerian moving window FDTD method. The basic idea of this moving window FDTD method is to select a proper window centering about the wave location to cover the whole wave packet. Then, at each time step, we just need to update the information inside this small window instead of the whole large region. As a result, the moving window FDTD solver is much more efficient than the FDTD approach in the stationary frame. Numerical examples of optical pulse propagation in both linear and nonlinear media are shown. When comparing the moving window FDTD method with the standard FDTD method in stationary frame, the error is less than 1% which is similar to the FDTD second order discretization error. (Received September 14, 2013)

1096-78-1402 **Yingxue Zhao*** (yzhao112@students.desu.edu). *Numerical Methods for Solving Cold-Fluid Maxwell's Equations with Applications to the Second Harmonic Generation from Metallic Nanoparticles.*

In this work, we develop a numerical method for solving the three-dimensional cold-plasma Maxwell's equations system that describes the electron gas dynamics driven by an external electromagnetic wave excitation. Our numerical approach is based on the Finite-Difference Time-Domain (FDTD) method for solving the Maxwell's equations and a finite difference method for the cold-fluid equations.

Numerical results show that our model is suitable for studying the second-harmonic generation (SHG) from metallic nanoparticles. (Received September 15, 2013)

1096-78-1621 **Justin Droba*** (drobajus@msu.edu), 6355 Beechfield Dr., Lansing, MI 48911. *A TD-DFT Approach to Second Harmonic Generation at Metal Surfaces.* Preliminary report.

Second harmonic generation is a simple nonlinear optical phenonemon in which a material converts incident light at frequency ω to that at 2ω. A classical model for the process at metal surfaces was developed by Nobel laureate Nicholaas Bloembergen using hydrodynamic equations. However, a multiphysics approach that combines modeling techniques from solid-state physics with linear response theory from time-dependent density functional theory (TD-DFT) provides a more appropriate framework to describe the process. The model's increased realism unfortunately is accompanied by a significantly involved chain of computations, each of which has its own challenges. In this talk, I will present the some of the basics of the TD-DFT modeling approach, provide a numerical example, and discuss some of the numerical techniques I used to demonstrate the example. (Received September 16, 2013)

1096-78-1626 **Jinjie Liu*** (jliu@desu.edu), Delaware State University, 1200 N Dupont Hwy, Dover, DE 19901, **Moysey Brio**, The University of Arizona, and **Jerome V Moloney**, The University of Arizona. *Transformation optics based local mesh refinement for solving Maxwell's equations.*

A novel local mesh refinement algorithm based on transformation optics (TO) has been developed for solving the Maxwell's equations of electrodynamics. The new algorithm applies transformation optics to enlarge a small region so that it can be resolved by larger grid cells. The transformed anisotropic Maxwell's equations can be stably solved by an anisotropic FDTD method, while other subgridding or adaptive mesh refinement FDTD methods require time-space field interpolations and often suffer from the late time instability problem. To avoid small time steps introduced by the transformation optics approach, an additional application of the mapping of the material matrix to a dispersive material model is employed. Numerical examples on scattering problems of dielectric and dispersive objects illustrate the performance and the efficiency of the transformation optics based FDTD method. (Received September 16, 2013)

1096-78-2041 **Ying He*** (he14@math.purdue.edu) and **Jie Shen** (shen7@purdue.edu). *Efficient spectral-element methods for acoustic scattering and related problems.*

I shall present the spectral element methods in combination with a transparent boundary condition for simulating acoustic scattering problems from periodic doubly layered media and unbounded rough surface respectively. The method uses a transformed field expansion to reduce the boundary value problem with a complex scattering surface into a successive sequence of transmission problems of the Helmholtz equation with a plane surface, which avoids not only the need for specialized quadrature rules but also the dense linear systems characteristic of boundary integral/element methods. Especially, for the scattering problems from the unbounded rough surface, Hermite orthonormal basis functions are used to further simply the transmission problems to fully decoupled one-dimensional two-point boundary value problems with piecewise constant wavenumbers, which can be solved efficently by a Legendre-Galerkin method. Ample numerical results will be presented to show the accuracy, stability, and versatility of our algorithms. (Received September 17, 2013)

1096-78-2183 **Jason M. Cornelius*** (jmcornelius10@students.desu.edu) and **Jinjie Liu** (jliu@desu.edu). *Numerical Simulation of the Space-Time Cloak.* Preliminary report.

In this work, we present a numerical method for solving the Maxwell's equations in bi-isotropic media. We utilize a dual grid FDTD method to provide a stable approach for the simulation of the bi-isotropic media with time and space varying permittivity, permeability and coupling coefficients. Our method is applied to simulate the space time cloak proposed by Martin W McCall et al [*J. Opt. 13*, 024003, 2011]. (Received September 17, 2013)

81 ▶ Quantum theory

1096-81-587 **Chandrashekar Channipura Madaiah*** (c.madaiah@oist.jp), 1919-1, Tancha, OIST, Quantum Systems Unity, Onna-son, Okinawa 9040495, Japan, and **Thomas Busch**. *Quantum walk as secured quantum memory.*

At a first look a dynamical process like a quantum walk appears to be an unlikely candidate for a quantum memory, since it results in nontrivial quantum correlations between the particle (qubit) and the position space. In this talk we present a careful analysis of the dynamics and show that the stored information of a qubit can be perfectly recovered at specific times t which are periodic and a function of coin parameter θ, used for evolving the walk. Due to the spatial spread of the qubit in position space, the information stored will also acquire an inherent level of security from an eavesdropper.

Though in principle this model describes a fully functioning quantum memory, the dependency of the recovery time t on θ and a linear increase in size of the position space required to store the information of the qubit poses an unwelcome and limiting restriction. By amending the protocol we show that one can recovery of the information at any time and independent of θ. Our protocol can be adopted to any quantum system for which experimental control over quantum walk dynamics can be achieved.

[1] arXiv : 1307.5922 (Received September 06, 2013)

1096-81-935 **Takuya Machida*** (machida@stat.t.u-tokyo.ac.jp), 515-4 Tookaichiba, Midori, Yokohama, Kanagawa 2260025, Japan. *Limit distribution of a 2-state quantum walk on the line with a delocalized initial state.*

Quantum walks are quantum analog of random walks. Since a limit distribution of a discrete-time quantum walk on the line was derived in 2002, a lot of limit theorems for the quantum walks with a localized initial state have been reported. In my presentation, we focus on a convergence theorem in distribution of a discrete-time 2-state quantum walk on the line with a delocalized initial state. From the theorem, we realize that the quantum walk can create the Gauss, Wigner semicircle, arcsine, and uniform distributions. The result in my presentation is based on [1].

[1] Machida, T.: Realization of the probability laws in the quantum central limit theorems by a quantum walk, Quantum Information and Computation, Vol.13 No.5&6, pp.430-438 (2013), arXiv:1208.1005. (Received September 11, 2013)

1096-81-1326 **Chaobin Liu*** (cliu@bowiestate.edu) and **Nelson Petulante**. *A class of primitive quantum channels.* Preliminary report.

In this study, we consider a special type of quantum channel characterized by exposure to a random environment, where the property of randomness is modeled by so-called i.i.d phases arranged as elements of the governing unitary matrix. In this context, the averaged motion of the quantum channel is shown to be primitive. Accordingly, this model permits an in-depth treatment of the role of decoherence and a detailed description of the quantum-to-classical transition. (Received September 14, 2013)

1096-81-1504 **Peter P Rohde*** (dr.rohde@gmail.com), Dept. Phys. & Astr., E6B Level 2, Macquarie University, 2109, Australia, and **Gavin Brennen** and **Alexei Gilchrist**. *Quantum walks with memory.*

In regular, discrete-time quantum walks, the Hilbert space is bipartite, comprising position and coin degrees of freedom. We introduce a formalism for quantum walks with memory, where the coin parameter is replaced with a register of coins that record the coin history going back a fixed number of steps. The walker evolves as a function of the coin register, which is updated via a memory function. We consider different memory functions and explore their effect on the dynamics of the walk. In one dimension, walkers with memory consistently exhibit ballistic speedup compared to classical walks. However, the choice of memory function drastically affects the dynamics and rate of spread. Measurement of the coin registers dramatically changes the dynamics of the walk. Next we consider a two-dimensional walk, and find that memory destroys the entanglement between the spatial dimensions, even when spatially entangling coins are employed. We present a physical model for how such a quantum walk might be implemented with linear optics, paving the way for experimental construction of such a walk. We discuss the computational power of multi-walker quantum walks with memory, and suggest that they might implement a classically hard algorithm, making them of experimental interest. (Received September 16, 2013)

1096-81-1993 **Salvador E. Venegas-Andraca*** (salvador.venegas-andraca@keble.oxon.org), Ap. postal 12-808, Narvarte, 03001 Mexico City, Mexico. *A quantum-walk based clustering algorithm.* Preliminary report.

Data clustering is a pervasive branch of computer science and computer engineering with many key applications in computer vision and bioinformatics, among several other fields.

Encouraged by relatively recent results on the computational universality of quantum walks, I shall introduce a quantum walk-based clustering algorithm and will compare the performance of this algorithm with some of its classical counterparts. (Received September 17, 2013)

1096-81-2227 **Fabiano M. Andrade*** (fmandrade@uepg.br), Dep. de Matemática e Estatística, Ponta Grossa, 84030900. *Green's function approach for quantum walks.*

Quantum walks are the quantum version of the classical random walks and constitute important tools in different applications, especially in quantum algorithms. A key aspect to explain different phenomena observed in quantum walks is the interference. So a description emphasizing the pathlike character of quantum walks is desirable. In this manner Green's function approach is particularly useful and is developed in this work. The exact formula has the form of a sum-over-paths and always can be cast into a closed analytic expression for arbitrary graph topologies and position-dependent quantum amplitudes. To a great extent the quantum walks usefulness is due to unusual diffusive features, allowing much faster spreading than their classical counterparts. Such behavior, although frequently credited to intrinsic quantum interference, usually is not completely characterized. Using the Green's function approach the problem dynamics in terms of a true Feynman sum-over-paths history is described. This allows one to explicitly identify interference effects and also to explain the emergence of superdiffusivity.
(Received September 17, 2013)

1096-81-2258 **Alexander Wilce*** (wilce@susqu.edu), Department of Mathematics, Susquehanna University, Selinsgrove, PA 17837. *Probabilistic foundations for quantum theory.*

It's well-known that quantum mechanics can be seen as a generalization of classical probability theory, in which random variables are replaced by self-adjoint elements of a C* algebra and probability measures, by states thereon. Unfortunately, this structure has proved difficult to motivate in purely probabilistic or operational terms. There has been no shortage of attempts to do so: inconclusive efforts in this direction include work of von Neumann in the late 1920s, as well as large part of the literature on quantum logic.

Recently, however, ideas from quantum information theory have led to remarkable progress on this question, as it pertains to *finite dimensional* systems. After quickly surveying some of this work, and its antecedents, I'll sketch a new approach having some advantages of simplicity, elegance and generality. (Parts of this talk represent joint work with Howard Barnum and Mathew Graydon.) (Received September 17, 2013)

1096-81-2414 **Santosh Kandel***, Department of Mathematics 255 Hurley, University of Notre Dame, Notre Dame, IN 46556. *Construction of a Functorial Euclidean QFT.* Preliminary report.

A d-dimensional Functorial Euclidean Quantum Field Theory E associates to a closed oriented Riemannian manifold Y of dimension $d-1$ a Hilbert space $E(Y)$ and to a bordism Σ from Y_1 to Y_2(which is a compact oriented Riemannian manifold with boundary $Y_2 \sqcup \bar{Y}_1$) a Hilbert-Schmidt operator $E(Y_1) \to E(Y_2)$ so that gluing bordisms corresponds to composing the associated operators. If we forget the Riemannian structure on the $Y's$ and on the bordisms there are many examples of such theories which are known as Topological Quantum Field Theories. In this talk, we construct an example of Functorial Euclidean QFT when d is even. (Received September 17, 2013)

82 ► Statistical mechanics, structure of matter

1096-82-1228 **Xingjie Helen Li*** (xingjie_li@brown.edu), 182 George St, Providence, RI 02912, and **Govind Menon**. *Title: Numerical solution of Dyson Brownian motion and a sampling scheme for invariant matrix ensembles.*

Abstract: The Dyson Brownian Motion (DBM) describes the stochastic evolution of N points on the line driven by an applied potential, a Coulombic repulsion and identical, independent Brownian forcing at each point. We use an explicit tamed Euler scheme to numerically solve the Dyson Brownian motion and sample the equilibrium measure for non-quadratic potentials. The Coulomb repulsion is too singular for the SDE to satisfy the hypotheses of rigorous convergence proofs for tamed Euler schemes by Kloeden et. al. Nevertheless, in practice the scheme is observed to be stable for time steps of $O(1/N^2)$ and to relax exponentially fast to the equilibrium measure with a rate constant of $O(1)$ independent of N. Further, this convergence rate appears to improve with N in

accordance with $O(1/N)$ relaxation of local statistics of the Dyson Brownian motion. This allows us to use the Dyson Brownian motion to sample $N \times N$ Hermitian matrices from the invariant ensembles. The computational cost of generating M independent samples is $O(MN^3)$. (Received September 13, 2013)

1096-82-1331 **Bridget K Toomey*** (toomeybr@math.miami.edu), **Chen Dan Dong**, **Xuchen Han** and **Verne Edward**. *Novel Approach for Evaluating Phases and Orientations of Polycrystalline Structures.* Preliminary report.

Rapid progress in material design has stimulated the need for the development of new tools for efficient and accurate identification of new structure features and properties. This task is relatively straightforward in the case where the new materials are either purely crystalline or purely amorphous. However, these structures are generally new unknown polycrystalline structures that are hard to describe or identify, as they can be made of different regions characterized by different morphology, element types, and orientations. Since the crystal structures and orientations of these composites are vital in understanding and manipulating their properties, researchers require an accurate characterization of the morphological properties at each region. However, no existing software can characterize polycrystals from the positions of their atoms. Therefore, it is urgent to develop such tools. Our method rectifies this gap in crystallography research by designing an algorithm based on the lattice reduction approach (Krivy and Gruber 1976), which has been used in monocrystalline identification. We modify Krivy and Gruber's algorithm to accommodate polycrystalline and amorphous, non-crystalline structures. (Received September 15, 2013)

1096-82-1666 **M. Yvonne Ou*** (mou@math.udel.edu), 408 Ewing Hall, Dept. Math. Sciences, University of Delaware, Newark, DE 19716. *On reconstruction of dynamic permeability and tortuosity of poroelastic materials.*

Dynamic permeability refers to the permeability of poroelastic media subjecting to oscillatory pressure gradient. It depends on both the frequency and the pore space geometry. The dynamic tortuosity is inversely related to the dynamic permeability and plays an important role in the mechanism of energy dissipation of waves through poroelastic materials. Numerically, dynamic tortuosity is the kernel in the memory term in the dissipation term for time domain wave equations; it is known to be associated with fractional derivative of order 1/2. In this talk, we will present our results on reconstructing the dynamic permeability as a function of frequency from partial data by utilizing its analytical properties when extending to the complex frequency plane. Using the relation between tortuosity and permeability, a set of quadratures are constructed for handling the memory term in the poroelastic wave equations. (Received September 16, 2013)

1096-82-1891 **Mark P Mueller*** (mark.mueller@ucdenver.edu) and **Lynn Bennethum**. *Coal Bed Methane: Micro-scale Models and Macro-scale Constraints.*

We develop a mathematical model for methane (natural gas) extraction from coal beds via carbon dioxide displacement. The model combines both a micro-scale statistical mechanics formulation and macro-scale thermodynamics concepts. This results in a model that describes gas adsorption, gas flow and swelling of the coal seam in a consistent manner using micro-scale information to produce a macroscopic model. (Received September 16, 2013)

86 ► Geophysics

1096-86-1116 **Peiliang Xu*** (pxu@rcep.dpri.kyoto-u.ac.jp), Disaster Prevention Research Institute, Kyoto University, Gokasho, Uji, Kyoto 611-0011, Japan. *Experimental evaluation of lattice reduction methods for discrete tomography.*

Reduction can be important to aid quickly estimating integer unknowns from noisy data for discrete tomography. We present an improved LLL algorithm with fixed complexity by extending a parallel reduction method for positive definite quadratic forms to lattice vectors. We propose the minimum angle of a reduced basis as an alternative quality measure of orthogonality, which is intuitively more appealing to measure the extent of orthogonality of a reduced basis. We conduct a large scale of experiments to evaluate five reduction methods, based on six quality measures of reduction. We investigate the mean running behaviors of the five rduction methods. The improved LLL algorithm with fixed complexity is shown to perform better than all the other reduction methods under study. The reduced Gram-Schmidt coefficients from experiments clearly show that they are not uniformly distributed but depend on the reduction algorithms used. They also clearly show that our improved LLL algorithm tends to produce small reduced Gram-Schmidt coefficients near zero with a larger probability and large reduced Gram-Schmidt coefficients near both ends of 0.5 and -0.5 with a smaller probability, implying that the quality of reduction may depend on the distribution of reduced Gram-Schmidt coefficients. (Received September 13, 2013)

1096-86-1399 **Christopher Harig*** (chris.harig@gmail.com), Guyot Hall 308, Princeton, NJ 08544, and **Frederik J. Simons** (fjsimons@gmail.com), Guyot Hall 321b, Princeton, NJ 08544. *Mapping ice mass loss on Greenland and Antarctica, in space and time.*

The melting of polar ice sheets is a major contributor to global sea-level rise. Antarctica is of particular interest since most of the mass loss has occurred in West Antarctica, however updated glacial isostatic adjustment (GIA) models and recent mass gains in East Antarctica have reduced the continent-wide integrated decadal trend of mass loss. Here we present a spatially and temporally resolved estimation of the Antarctic ice mass change using Slepian localization functions. With a Slepian basis specifically for Antarctica the functions maximize their energy on the continent and we can project the geopotential fields into a sparse set of orthogonal coefficients. By fitting polynomial functions to the limited basis coefficients we maximize signal to noise and need not perform smoothing or destriping filters common to other methods. In addition we determine an empirical noise covariance matrix from the GRACE data to estimate the uncertainty of mass estimation. When applied to large ice sheets, as in our recent Greenland work, this technique is able to resolve both the overall continental integrated mass trend, as well as the spatial distribution of the mass changes over time. (Received September 15, 2013)

1096-86-1401 **Alain Plattner*** (plattner@princeton.edu), Guyot Hall 317, Princeton, NJ 08544, and **Frederik J. Simons** (fjsimons@gmail.com), Guyot Hall 321b, Princeton, NJ 08544. *Planetary potential-field inversion from vectorial data: Using Slepian functions for varying satellite altitude.*

When inverting for a planet's gravity or magnetic field from satellite data, the space between the surface and the satellite is considered source-free. This renders the field outside of the planet harmonic, and the inversion a reevaluation of the field at a different altitude. If we express the field in a bandlimited spherical-harmonics basis, the reevaluation on the planet's surface from a single satellite altitude is an intrinsically poorly conditioned linear transformation. If the data are of strongly varying quality or only locally available, the method will become unstable and we need to find an alternative procedure. In this presentation we show how we can use the spatiospectral concentration concept by Slepian, Landau, and Pollak to construct a potential-field inversion method for vector data on a sphere. In order to account for the poorly-conditioned reevaluation of the field on the planet's surface we incorporate the required transformation directly into the construction of our so-called Slepian functions. We present how the potential-field inversion emerging from this concept can stably estimate a crustal field within a target region from data only within that region while accounting for varying satellite altitude. (Received September 15, 2013)

1096-86-2438 **Daniel H Rothman*** (dhr@mit.edu), Lorenz Center, Department of Earth, Atmos, and Plan Sci, Massachusetts Institute of Technology, Cambridge, MA 02139. *Earth's Carbon Cycle: A Mathematical Perspective.*

The carbon cycle represents metabolism at a global scale. When viewed through a mathematical lens, observational data suggest that the cycle exhibits an underlying mathematical structure. This talk focuses on two types of emerging results: evidence of global dynamical coupling between life and the environment, and an understanding of the ways in which smaller-scale processes determine the strength of that coupling. Such insights are relevant not only to predicting future climate but also to understanding the long-term co-evolution of life and the environment. (Received September 17, 2013)

90 ► Operations research, mathematical programming

1096-90-204 **Ram N Mohapatra*** (ram.mohapatra@ucf.edu), 4000 Central Florida Blvd., Department of Mathematics, Orlando, FL 32817, Afghanistan, and **Ram U Verma** (verma99@msn.com), 601 University Drive, San Marcos, FL 78666-4684. *Exponential Type* $A-(b,phi,eta,p,r)$ *Univexities and Minimax Fractional Integral Programming.*

Recently, Verma (Theory and Applications of Mathematics & Computer Science 2 (2) (2012) 31–47 and 3 (1) (2013) 65–84) has considered comprehensive generalization of the concept of univex functions and their applications introduced by Zalmai (Advances in Nonlinear Variational Inequalities 15(2), 63–91). This paper deals with exponential type $A-(b,$phi,eta$,p,r)$ univexities and the problem of minimizing a maximum of several time dependent ratios involving integral expressions. Based on these generalized univexities some optimality conditions are established and dual models of Wolf and Mond types as well as one parameter and mixed types are considered. They lead to weak, strong and strict converse duality theorems. (Received August 17, 2013)

1096-90-205 **Ram U Verma*** (verma99@msn.com). *General Efficiency Conditions for Multiobjective Fractional Programming Problems on Higher Order Invexity Frameworks.* Preliminary report.

Based on a general class of parametric sufficient efficiency conditions for multiobjective fractional programming problems relating to higher order invexity frameworks, some efficient solutions to multiobjective fractional programming problems are investigated. (Received August 17, 2013)

1096-90-1441 **Bistra Dilkina*** (bistra@cs.cornell.edu) and **Claire A Montgomery** (claire.montgomery@oregonstate.edu). *Applications of graph theory to optimize wildlife corridor systems for multiple species: Grizzly bear and wolverines in the northern Rockies.* Preliminary report.

Maintaining connectivity between habitat core areas is important for combating the effects of habitat loss and fragmentation facing species of concern. However, conservation efforts are implemented under very limited economic resources. Therefore designing cost-efficient approaches for landscape connectivity is an important and challenging computational task. This paper reports ongoing research in the application of graph theory approaches to the problem of optimally designing wildlife corridors to connect established reserves for multiple species. To obtain conservation strategies that minimize cost while achieving connectivity for multiple species, we introduce the Steiner Multigraph Problem. Going beyond least cost solutions, we propose the Minimum Delay Generalized Steiner Network problem for finding the corridors with minimum landscape resistance to movement subject to a budget constraint. This model also addresses the need for robust conservation plans by supporting multiple disjoint corridors between pairs of reserves. We apply our approach in western Montana to demonstrate how the solutions may be used to study trade-offs in connectivity for two species with different habitat requirements and differently located core areas – the grizzly bear and the wolverine. (Received September 15, 2013)

1096-90-1687 **Uday V Shanbhag*** (udaybag@psu.edu), Industrial and Manufacturing Engg., 310 Leonhard Building, State College, PA 16803. *Stochastic Approximation Schemes for Stochastic Variational Inequality Problems.*

We consider the finite-dimensional stochastic variational inequality problem, a stochastic generalization of the standard variational variational inequality problem. We discuss some of our recent stochastic approximations designed for such problems, including the development of regularized variants of stochastic approximation, self-tuned steplength schemes, and most recently extragradient generalizations to the stochastic regime. Time permitting, we discuss analogous schemes in the context of learning and computation. (Received September 16, 2013)

1096-90-1823 **Geetanjali Panda***, Department of Mathematics, Indian Institute of Technology, Kharagpur, Kharagpur, WestBengal 721302, India, and **Chakraborty Suvra Kanti**, Department of Mathematics, Indian Institute of Technology, Kharagpur, Kharagpur, WestBengal 721302. *Extension of Golden Section Search method to Higher Dimensional Optimization Problem.*

Golden Section and Fibonacci search methods due to Kiefer are gradient free numerical optimization techniques which find the minimum of a strictly quasi-convex function of a single variable over an interval by successive iteration. Methods of Rosenbrock, Zangwill, Hooke and Jeeves are familiar derivative free search procedures for minimizing or maximizing functions in higher dimensions. These methods employ discrete steps along search directions. Gradient free multidimensional search method due to Nelder Mead, which is a MATLAB's built in command, looks at the functional values at the extreme points of the simplex. In every iteration, the worst extreme point is rejected and replaced by a new one along the line joining this point and the centroid of the remaining points. The process is repeated until a suitable termination criterion is satisfied. This paper extends the Golden Section search method to multidimensional optimization problems and to strictly quasi-convex functions. An algorithm is proposed and the methodology is illustrated graphically for two dimensions. (Received September 16, 2013)

1096-90-1846 **Rick Chartrand*** (rickc@lanl.gov), Theoretical Division, MS B284, Los Alamos National Laboratory, Los Alamos, NM 87545. *Generalized shrinkage and penalty functions.*

A key ingredient in many algorithms for ℓ^1 minimization is that the solution of an ℓ^1-penalized least squares problem (in other words, the *proximal mapping* of the ℓ^1 norm) has a simple, explicit solution, given by the mapping known as soft thresholding. The fact that the solutions to many ℓ^1 problems are sparse is related to the way soft thresholding acts to shrink the magnitudes of components. These properties of the ℓ^1 norm are sufficiently useful that in this talk, we construct new penalty functions by first specifying a shrinkage function, and then seeking the penalty function having it as a proximal mapping. By imposing conditions on our shrinkage function, we can guarantee that the resulting penalty function has desirable properties for producing sparse solutions. We will show examples of this process, including a new penalty function that leads to image reconstruction from fewer measurements than ever before. (Received September 16, 2013)

1096-90-2020 **Christiane Tammer*** (christiane.tammer@mathematik.uni-halle.de), Institute of Mathematics, 06099 Halle, Germany, and **Kathrin Klamroth**, **Elisabeth Koebis** and **Anita Schoebel**. *A unified approach for different concepts of robustness and stochastic programming via nonlinear scalarizing functionals.*

We show that many different concepts of robustness and of stochastic programming can be described as special cases of a general nonlinear scalarization method by choosing the involved parameters and sets appropriately. This leads to a unifying concept which can be used to handle robust and stochastic optimization problems. Furthermore, we introduce multiple objective (deterministic) counterparts for uncertain optimization problems and discuss their relations to well-known scalar robust optimization problems by using the nonlinear scalarization concept. (Received September 17, 2013)

1096-90-2021 **Behnam Soleimani*** (behnam.soleimani@mathematik.uni-halle.de), Institute of Mathematics, Halle, 06099, and **Christiane Tammer**. *Vectorial Ekeland's variational principle with respect to the variable order structure.*

There are many generalization of Ekeland's variational priciple for vector optimization problem with fix order structure. Here, we presenet a generalization of Ekeland's variational principle for vector optimization problem with respect to variable order structure. First, we introduce concepts for approximate minimal, approximate nondominated solutions and approximate minimizers of vector optimization problems with respect to a variable order structure. The different concepts for approximate solutions are illustrated by several examples. Variational principles for vector optimization problems with variable order structure are derived. Finally, we give some necessary conditions for approximate solutions of vector optimization problems with variable order structure. (Received September 17, 2013)

1096-90-2242 **Charles N Glover*** (glover_charles@bah.com), Annapolis Junction, MD 20701, and **Michael O. Ball** (mball@rhsmith.umd.edu), Robert H. Smith School of Business, College Park, MD 20742. *Sparse Monge Matrices Arising from Scheduling Problems.*

It was recently shown that a certain stochastic scheduling problem arising in air traffic flow management could be solved by a simple greedy algorithm. Here, I will relate this result to Monge matrices and Monge sequences and show how this result applies to a more general class of scheduling problems. (Received September 17, 2013)

1096-90-2299 **Mutiara Sondjaja*** (ms999@cornell.edu), 257 Rhodes Hall, Ithaca, NY 14850, and **James Renegar** (renegar@orie.cornell.edu), 230 Rhodes Hall, Ithaca, NY 14850. *A quadratic cone relaxation-based algorithm for linear programming.* Preliminary report.

We present and analyze a linear programming algorithm based on replacing the non-negative orthant with larger quadratic cones. For each quadratic relaxation that has an optimal solution, there naturally arises a parameterized family of quadratic cones for which the optimal solutions create a path leading to the linear program's optimal solution. We show that this path can be followed efficiently, thereby resulting in an algorithm whose complexity matches the best bounds proven for interior-point methods. Furthermore, this algorithm can be extended for the larger classes of semidefinite programming and hyperbolic programming problems, with similar iteration-complexity bounds. (Received September 17, 2013)

1096-90-2507 **Sofya Chepushtanova*** (chepusht@math.colostate.edu), Department of Mathematics, 1874 Campus Delivery, Fort Collins, CO 80523-1874, and **Michael Kirby**. *Pattern Classification by Ellipsoidal Machines Using Semidefinite Programming.*

We explore ellipsoidal machines for pattern classification problem. The goal is to find the smallest ellipsoid that contains all the points of one class and none of the other. The problem is formulated as a semidefinite program (SDP) that is more general than a linear program. The SDP can be solved successfully by most interior-point methods, in particular by primal-dual path-following algorithm. This approach, applied to diagnosis of neonatal sepsis, can be used as an effective early warning technique. (Received September 17, 2013)

1096-90-2651 **Dung T. Nguyen*** (dn5963@bard.edu), 30 Campus Road, Annandale-on Hudson, NY 12504, and **Mikaela Cashman**, **Keenan Hawekotte** and **Elizabeth Newman**. *Bar Code Localization in Images Using Neural Network and Linear Discriminant Analysis Frameworks.*

We develop an algorithm for the automatic localization of 1-D bar codes in images using machine learning techniques. Despite the ubiquity of operational bar code scanners, we focus on low resolution camera-based scanners and challenging environments where traditional methods fail. We develop attributes that help distinguish bar codes from other objects in the image such as text and logos. These attributes are based on the discrete wavelet transform (DWT), the discrete Fourier transform (DFT), and gradient analysis. To create a bar code detection process robust to image distortions such as rotation, glare, noise, oblique viewing angle, uneven and dim illumination, and an abundance of surrounding text, we use the information from our individual detection methods in neural network, linear discriminant analysis (LDA) frameworks, and simple boosting. We analyze the effectiveness of these attributes and report on performance for a range of degraded images. (Received September 17, 2013)

91 ► Game theory, economics, social and behavioral sciences

1096-91-73 **Bin Mei*** (bmei@uga.edu), 180 E Green St, Athens, GA 30602. *Valuing a timber harvest contract as a high-dimensional Amercian call option via least-squares Monte Carlo simulation.*

Industrial timberland ownership in the US has shifted substantially in the last 20 years. Having sold their fee-owned timberlands, forest products companies relied heavily on the open market for raw timber. To reduce their exposure to market risks, however, forest products companies have been using a number of supply chain instruments such as timber harvest contracts. As these vehicles become increasingly important to the forest industry, it is necessary and important to determine their economic values. In this study, we treated a 3-year timber harvest contract on a 30-year-old loblolly pine plantation as a high-dimensional American call option and calculated its value by the least-squares Monte Carlo simulation technique. The estimated values of such a contract ranged from $1,693/acto$1,984/ac under two timber price assumptions. With reasonable starting timber prices and strike price in the simulation, random timber prices led to higher contract values. Results from this study can help private landowners, timber brokers, and forest products companies better manage their business risks. (Received July 10, 2013)

1096-91-360 **Elliott H Lieb*** (lieb@princeton.edu). *Strichartz Inequality for Orthonormal Functions.*

We prove a Strichartz inequality for a system of orthonormal functions, with an optimal behavior of the constant in the limit of a large number of functions. The estimate generalizes the usual Strichartz inequality, in the same fashion as the Lieb-Thirring inequality generalizes the Sobolev inequality. As an application, we consider the Schrödinger equation in a time-dependent potential and we show the existence of the wave operator in the strong sense of a finite Schatten space norm. (joint work with R. Frank, M. Lewin and R. Seiringer) (Received August 30, 2013)

1096-91-431 **Jan Rychtar*** (rychtar@uncg.edu), Department of Mathematics and Statistics, UNCG, Greensboro, NC 27412, and **Mark Broom**, Department of Mathematics, City University London, London, United Kingdom. *The evolution of cooperation - kin selection and greenbeard genes.*

One way to convince ourselves that no cooperation can evolve among defectors is via a simple yet one of the most famous games in all of game theory - the Prisoner's dilemma (PD) game. The players of this game adopt one of the two strategies: a) a cooperator who pays a cost so that another individual can receive a benefit, or b) a defector who can receive benefits, but it has no cost as it does not deal out any benefits at all. As seen from this formulation, no rational individual would opt to be a cooperator. Yet, we can see cooperation everywhere around us and thus (assuming defectors were here first) there must exist at least one mechanism for its evolution. Nowak (2006, 2012) discusses several of such mechanisms, including the kin selection by which cooperation can spread if the benefits go primarily to genetic relatives. In this talk we will introduce a simple PD-like asymmetric matrix game and show how Hamilton's rule can easily be recovered. We will also introduce a simple PD-like symmetric matrix game to model the evolution of cooperation via greenbeard mechanism, which can be seen as a special case of kin selection. (Received September 03, 2013)

1096-91-567 **Ethan Akin*** (ethanakin@earthlink.net), Mathematics Department, The City College, 137 Street and Convent Avenue, New York, NY 10031. *Iterated Prisoners Dilemma: Dynamics of Zero-Determinant Strategies.*

The Markov model for the Iterated Prisoners Dilemma has been much studied but recent work by Press and Dyson has introduced some new approaches. This work has lead to a complete description of the "good strategies" which represent, in a reasonable sense,solutions for the IPD. Some of these occur within the co-dimension one class of Zero Determinant Strategies introduced by Press and Dyson. Furthermore, if competition is restricted to strategies from this class, the evolutionary dynamics has interesting properties (Received September 06, 2013)

1096-91-1196 **Rachel Popp*** (rachel.popp@gmail.com), **Jason Jaeckel**, **Amanda Rose**, **Christie Burris**, **Francis Motta** and **Eric Hanson**. *An Exploration of Methods of Solving the Combinatorial Game Flood-it.*

Flood-It is a game consisting of an $n \times n$ grid where each entry is one of k colors. The player starts with one block whose color he controls. The objective is to turn the board all one color. The player switches the color of his controlled block(s) to a color of his choosing, any of the adjacent blocks of the same color are then under his control. The player floods the board by repeating this process. A natural question is how to minimize the number of moves used to flood the board. We demonstrate a version of Flood-It, implemented in Matlab, which we use to develop and analyze algorithms that flood the board. We also consider questions about the space of all boards. For example, what is the integer M such that every $n \times n$ board with k colors can be solved in at most M moves? Finally, we consider generalizations of this game, including boards on compact surfaces. (Received September 13, 2013)

1096-91-1507 **Bao Q TRUONG*** (btruong@nmu.edu), Presque Isle Avenue, Department of Mathematics & Computer Science, Northern Michigan University, Marquette, MI 49855. *Necessary nondomination conditions in multiobjective optimization with variable ordering structures.* Preliminary report.

In this talk we study the concept of nondomination in problems of multiobjective optimization with variable ordering structures, which reduces to Pareto efficiency when the ordering structure is constant/nonvariable. Based on advanced tools of variational analysis and generalized differentiation, we develop verifiable necessary conditions for nondominated solutions to multiobjectve optimization problems with general geometric constraints that are new in both finite and infinite dimensions. Many examples are provided to illustrate and highlight the major features of the obtained results. (Received September 16, 2013)

1096-91-1718 **Weicheng Ye*** (yeweichengsuper26@hotmail.com), 56-32 206th street, Oakland Gardens, NY 11364. *Modeling and Analysis of Strategies in the Symmetric and Asymmtric El Farol Problem.* Preliminary report.

The El Farol Problem is related to minority games where agents use mixed strategies to make attendance decisions. Cross et al. established a strategy of asymmetric game based on agents' dominant psychological characteristic. In this research, we establish both symmetric and asymmetric El Farol games. Due to agents' psychological behavior and the unpredictable occurrence, we introduce noise and strategies for periodicity recognition. We compute the hamming distance to see agents' decision based on the same strategy space. We then analyze the model to test the periodicity, and establish the comparison of strategies between symmetric and asymmetric games. We study the agents' attendance's relationship to the past aggregate or individual attendance/minority side history. In the last section, we compare our program result of attendance behavior to the experimental result. Our results suggest that the simple model of human decision making in the El Farol game suggested by Cross et al, when modified with noise and periodicity recognition, is broadly consistent with experimental data in the symmetric game scenario. When the model is extended to deal with the asymmetric game we postulate, based upon the above observations, that the aggregate behavior is far less efficient. (Received September 16, 2013)

1096-91-1782 **Yuanying Guan*** (guany@iun.edu), 3400 Broadway, Gary, IN 46408. *Systemic Risk and Financial Contagion in Agent-Based Networks.*

The recent financial crisis highlighted the importance of understanding the financial system as a complex interacting system. The relationship between network structure and systemic risk in contagion processes has been studied a lot since then. In this paper, we focus on the contribution of heterogeneity in financial networks. We start from analysis of simple financial networks, and investigate how heterogeneous structures and agents' interactions will impact the extent of contagion. Furthermore, we explore the evolution of these networks in agent-based scenarios.

(Received September 16, 2013)

1096-91-1821 **Zachary Feinstein*** (zfeinste@princeton.edu) and **Birgit Rudloff**. *Time consistency of risk measures in markets with transaction costs.*

In markets with transaction costs, when capital requirements can be made in a basket of currencies or assets, risk measures are naturally set-valued functions. Definitions of different time consistency properties in the set-valued framework are given. In the set-valued case, the recursive form for multivariate risk measures, an additive property for the acceptance sets, an additive property for penalty functions (for convex risk measures), and a version of m-stability (for coherent risk measures) are all equivalent to a stronger time consistency property called multi-portfolio time consistency. As examples, we consider the superhedging problem in markets with proportional or convex transaction costs and the set-valued average value at risk. (Received September 16, 2013)

1096-91-2092 **Jagdish Chandra*** (jagdish.chandra@comcast.net), Jagdish Chandra, 6504 Great Drum Circle, Columbia, MD 21044, and **G S Ladde** (gladde@usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, CMC 342, Tampa, FL 33620-5700. *Energy Method for Dynamic Social Networks.* Preliminary report.

Connectivity is the hallmark of emerging world order. This is manifested through competition, cooperation, and conflicts in social, economic, and human activities. We model such behavior as interacting dynamical systems under random internal and/or external environments. Specifically, using energy-like function along with the appropriate framework of differential inequalities, we derive simple and explicit conditions that lead to interesting qualitative properties and quantitative estimates for such networked dynamic behavior. (Received September 17, 2013)

1096-91-2303 **Tim Hsu** (hsu@math.sjsu.edu) and **Charles Petersen*** (petersenc19@yahoo.com). *Upset-downset.* Preliminary report.

Let P be a finite poset. For $x \in P$, recall that the *downset* and *upset* of x are defined to be $\check{x} = \{y \in P \mid y \leq x\}$ and $\hat{x} = \{y \in P \mid y \geq x\}$, respectively. We define the *upset-downset game* $G(P)$ to be the game with the following possible moves: For any $x \in P$, **Left** may remove the downset of x, leaving the game $G(P - \check{x})$; and for any $x \in P$, **Right** may remove the upset of x, leaving the game $G(P - \hat{x})$. The first player unable to move loses, i.e., $G(\emptyset) = 0$. By standard results, we see that upset-downset is a partizan game whose values are all infinitesimal ("all small").

This talk describes our work in two special cases of upset-downset. In the case where the Hasse diagram of P is a disjoint union of complete bipartite graphs, we exhibit a winning strategy for any winnable position. We also describe preliminary results in the case where P is a rank 2 poset where the downset of every rank 2 element x contains exactly two elements of rank 1. (Such posets may be thought of as graphs, where the rank 2 elements come from edges and the rank 1 elements come from vertices.) (Received September 17, 2013)

92 ► Biology and other natural sciences

1096-92-22 **Zhilan Feng*** (zfeng@math.purdue.edu), 150 N University st., Math Department, Purdue University, West Laayette, IN 47907. *Plant toxins and trophic cascades alter fire regime and succession on a boreal forest landscape.*

Earlier models of plant-herbivore interactions relied on forms of functional response that related rates of ingestion by herbivores to mechanical or physical attributes such as bite size and rate. These models fail to predict a growing number of findings that implicate chemical toxins as important determinants of plant-herbivore dynamics. Specifically, considerable evidence suggests that toxins set upper limits on food intake for many species of herbivorous vertebrates. We developed mathematical models with toxin-determined functional responses to study the effects of inter-specific plant competition, herbivory, and a plant's toxic defenses against herbivores on vegetation dynamics. The new modes exhibit much more complex dynamics including Hopf- and homoclinic-bifurcations. We used the model to estimate the effects of different management policies such as the levels of wolf control. Simulations indicated that management reductions in wolf densities could reduce the mean time to transition from deciduous to spruce by more than 10 years, thereby increasing landscape flammability. The integrated model can be useful in estimating ecosystem impacts of wolf control and moose harvesting in central Alaska. (Received May 22, 2013)

1096-92-122 **Jin Wang***, Department of Mathematics, Old Dominion University, Norfolk, VA 23529. *Modeling water-borne diseases: Environmental, ecological and climatic interaction.* Preliminary report.

We consider mathematical modeling of a class of water-borne infectious diseases, particularly cholera, where ecological and climatic factors, human-environment interactions, and human-human direct interactions all play important roles in their transmission dynamics. We formulate a general compartmental model based on a system of nonlinear differential equations and investigate the multiple transmission pathways in shaping the epidemics and endemics of the diseases. Realistic case studies are employed to validate the analytical prediction. In addition, we discuss the impacts of seasonal variation and climatic change on disease dynamics, using both mathematical analysis and numerical simulation. (Received August 01, 2013)

1096-92-188 **Linh Ngoc Khanh Huynh*** (linh.n.huynh@rice.edu). *Mathematically Decomposing an Ecological Network into Self-Sustaining Building Blocks.*

An ecological network can be represented by a directed, weighted graph whose nodes are the compartments of the network, edges are the flows or transactions of materials, and weights of the edges are the flow rates. Studying systemwide properties of some complex ecological networks can be easier when we study those properties in the networks' building blocks instead. However, it would not be ecologically meaningful if compartments and flows are studied separately because they exist together as a network. Hence, we propose a new building block called flux, which is the smallest process in an ecological network that can theoretically sustain itself. It is either a simple cycle or simple chain. Any ecological network, regardless of size or complexity, has a finite unique set of fluxes. I am going to present how to decompose any ecological network into fluxes using a linear algebra approach, a computational approach, and a probabilistic approach and also discuss the flux coefficient uniqueness issue of these methods. This individual project was done through a joint Research Experiences for Undergraduates (REU) program between University of Georgia and the Mathematical Biosciences Institute thanks to a support from the National Science Foundation. (Received August 15, 2013)

1096-92-244 **Lake R Ritter*** (lritter@spsu.edu), SPSU-Dept. of Mathematics, 1100 S. Marietta Pkwy, Marietta, GA 30060. *A mathematical model of macrophage reverse cholesterol transport by high density lipoproteins.*

The accumulation of fat deposits in the arterial wall is a hallmark of atherosclerosis. High density lipoproteins may serve a number of anti-atherogenic purposes—among them the removal of excess cholesterol from the tissue including lipids bound to forming foam cells (lipid laden immune cells). A model of foam cell formation including reverse cholesterol transport will be offered. Steady state and numerical analyses of the equations will be presented. (Received August 22, 2013)

1096-92-279 **Laurel A. Ohm*** (laurelohm@gmail.com). *Folic acid supplementation and recovery from spinal cord injury: a mathematical model.* Preliminary report.

The folate cycle is vital to the human body, serving, among other functions, as an important step in DNA methylation. Injuries to the spinal cord and central nervous system (CNS) tissues have been shown to alter folate distribution in the body, causing a decrease in concentration of methionine synthase, the main methyl donor. Folic acid, a folate form rarely found in natural foods, has been shown to increase neuronal regeneration following CNS injury when taken as a dietary supplement. Additionally, experimental data shows biphasic concentration changes in methionine synthase and other key players in the folate cycle in response to increasing doses of folic acid, suggesting that moderate supplementation best enhances regeneration. To determine a possible mechanism for the observed biphasic neuronal regeneration, an existing ODE model of folate metabolism was modified to account for CNS injury and subsequent folic acid supplementation. The resulting model suggests that the experimentally observed changes to the folate cycle may relate to the cell's folic acid uptake scheme, especially concentration-dependent changes in folic acid receptor FolR1 activity and competitive inhibition of folic acid uptake by other folate substrates. (Received August 26, 2013)

1096-92-406 **David Murrugarra*** (davidmur@math.gatech.edu), School of Mathematics, Atlanta, GA 30332-0160. *Modeling Stochasticity and Variability in Gene Regulatory Networks with Applications for Optimal Control.*

Modeling stochasticity in gene regulation is an important and complex problem in molecular systems biology. This talk will introduce a discrete stochastic modeling framework for gene regulatory networks. This framework incorporates propensity parameters for activation and degradation and is able to capture the cell-to-cell variability. It will be presented in the context of finite dynamical systems, where each gene can take on a finite number of states, e.g. Boolean Networks, and where time is also a discrete variable. Applications using methods from control theory will be presented for the purpose of designing optimal control strategies. A background to stochastic modeling will be given and applications will use two of the best known stochastic regulatory networks, the outcome of lambda phage infection of bacteria and the p53-mdm2 complex. (Received September 02, 2013)

1096-92-416 **Judith R Miller***, jrm32@georgetown.edu. *Adaptation of complex traits in biological invasions.* Preliminary report.

It is widely acknowledged that adaptation plays a key role in the establishment and spread of invasive species, but few theoretical studies of this problem exist. Here we incorporate nongenetic population characteristics known to affect invasion speed and success into a modified version of a classic spatial genetic model due to Kirkpatrick and Barton. We present numerical results that help resolve the apparent sharp disparity between outcomes of the Kirkpatrick-Barton model and of the corresponding model in which genetic variance, the raw material of adaptation evolves freely. We also examine the state of rigorous analysis of this family of models. (Received September 03, 2013)

1096-92-470 **Abdul-Aziz Yakubu*** (ayakubu@howard.edu), Department of Mathematics, Howard University, 2441 6th Street NW, Washington, DC 20509, and **Najat Ziyadi**, Department of Mathematics, Morgan State University, Baltimore, MD 21251. *Bifurcations In A Discrete-Time SIMS Epidemic Model with Predator-Induced and Mating Limitation-Induced Allee Effects.*

In this talk, we will use a Susceptible–Infected–Immune–Susceptible (SIMS) discrete-time epidemic model that incorporates both predator-induced and mating limitation-induced Allee effects in the demographic dynamics to study the bifurcations that occur in the system with and without the infectious disease. (Received September 04, 2013)

1096-92-473 **Abdul-Aziz Yakubu*** (ayakubu@howard.edu), Mathematics Department, Howard University, 2441 6th Street NW, Washington, DC 20059, and **Avner Friedman**, Department of Mathematics and MBI, The Ohio State University, Columbus, OH. *A Bovine Babesiosis Epidemic Model With Dispersion.* Preliminary report.

Bovine Babesiosis (BB) is a tick borne parasitic disease with worldwide over 1.3 billion bovines at potential risk of being infected. The disease, also called tick fever, causes significant mortality from infection by the protozoa upon exposure to infected ticks. An important factor in the spread of the disease is the dispersion or migration of cattle as well as ticks. In this talk, we study the effect of this factor in both constant and periodic environments. Based on data from Colombia, South Africa and Brazil, we use the model to determine the effectiveness of several intervention schemes to control the progression of BB. (Received September 04, 2013)

1096-92-566 **Kathryn G. Workman*** (kate.workman@richmond.edu), **Shuang Zhao** (shuang.zhao@richmond.edu) and **John W. Cain** (jcain2@richmond.edu). *Restricted Feedback Control of a Cardiac Arrhythmia.*

When an equilibrium state of a physical or biological system suffers a loss of stability (e.g., via a bifurcation), it may be both possible and desirable to stabilize the equilibrium via closed-loop feedback control. In our study, the desired equilibrium state is a normal heart rhythm, and feedback control is intended to prevent a bifurcation to an abnormal rhythm known as T-wave alternans. Using a discrete-time model of cardiac rhythm, we simulate and mathematically analyze an algorithm known as time-delay autosynchronization (TDAS) as a means of preventing alternans. TDAS works by making small adjustments (perturbations) to the heart rate during each beat. Our analysis improves upon prior studies in two ways. First, we generalize TDAS so that perturbations need not be required during every beat. Second, our model of heart rhythm incorporates short-term "memory" in the sense that each beat is influenced by several previous beats. (Received September 06, 2013)

1096-92-754 **Yunshyong Chow**, Taipei, Taiwan, and **Sophia Jang*** (sophia.jang@ttu.edu), Lubbock, TX 79409. *Multiple attractors in a Leslie-Gower competition system with Allee effects.*

We discuss the asymptotic dynamics of the classical Leslie-Gower competition model when both competing populations are subject to Allee effects. The system may possess four interior steady states. For certain parameter regimes, both competing populations may either go extinct, coexist, or one population drive the other population to extinction depending on initial conditions. (Received September 09, 2013)

1096-92-756 **Eric S Numfor*** (numfor@math.utk.edu), 1403 Circle Drive, 227 Ayres Hall, Knoxville, TN 37996. *Optimal Control and Analysis of a Coupled ODE/PDE Immuno-epidemiological Model.*

We formulate an immuno-epidemiological model of coupled within-host model of ODEs and between-host model of ODE and PDE. Existence and uniqueness of solution to the between-host model is established, and an explicit expression for the basic reproduction number of the between-host model derived. Stability of disease-free and endemic equilibria is investigated. An optimal control problem with drug-treatment control on the within-host system is formulated and analyzed. Numerical simulations based on the forward-backward sweep method are obtained. (Received September 10, 2013)

1096-92-814 **Anna Mummert*** (mummerta@marshall.edu), **Roger Estep**, **Robert Hughes** and **Jessica Shiltz**. *Agent-based Modeling of Pandemic Influenza.* Preliminary report.

A striking characteristic of influenza pandemics is the multiple peaks of infection. For example, the United States has experienced two peaks of infection in each of the past four influenza pandemics, one peak during the summer months and a second peak during the typical flu season. In contrast, the number of infected individuals peaks only once during a seasonal flu. The mechanisms that cause the multiple peaks of infection during pandemic influenza seasons are not well understood. The goal of this project is to use agent-based modeling to investigate mechanisms that can generate two peaks of infection. In this project, we describe the susceptible-exposed-infectious recovered (SEIR) agent-based model developed in Netlogo for simulating the 2009 H1N1 influenza pandemic. The incubation and infectiousness periods are drawn from gamma distributions. The model is calibrated by matching known average daily contacts and key epidemiological quantities, such as the basic reproduction number, the number of new infections generated from one infectious person at the beginning of the outbreak. Also, we explore the results of model simulations that include waning immunity, which is one potential mechanism for generating multiple peaks of infection. (Received September 10, 2013)

1096-92-880 **Shandelle M. Henson*** (henson@andrews.edu), **J. M. Cushing** and **James L. Hayward**. *Reproductive synchrony in populations can ameliorate the effects of adult-on-juvenile cannibalism.* Preliminary report.

Ovulation synchrony has been found in humans, rats, and birds. Field studies of two species of colonial gulls demonstrate ovulation synchrony, with the level of synchrony increasing with nest density. These birds also cannibalize eggs during times of decreased resource availability. We consider proof-of-concept models of populations with adult-on-juvenile cannibalism and reproductive synchrony. The models suggest that cannibalism may be an adaptive response to decreased resource and, in turn, reproductive synchrony may be an adaptive response to cannibalism. (Received September 10, 2013)

1096-92-887 **Jim M Cushing*** (cushing@math.arizona.edu), Department of Mathematics, University of Arizona, 617 N Santa Rita, Tucson, AZ 85721, and **Shandelle Henson** and **James Hayward**. *Cannibalism can allow survival of a population endangered by decreased environmental resource availability.* Preliminary report.

Several field studies of marine birds (glaucous-winged gull breeding colonies) on Protection Island National Wildlife Refuge in the Strait of Juan de Fuca (State of Washington, USA) motivate mathematical "proof-of-concept" models designed to investigate plausible causal mechanisms of observed changes in population dynamics and life history strategies. This lecture will focus on one of these phenomena, namely, increased cannibalism in response to decreased environmental resource availability. Mathematical analysis of a model describing the dynamics of a cannibalistic population (using the Fundamental Bifurcation Theorem for matrix population dynamic models) shows that low resource availability and high cannibalism intensity result in a backward bifurcation and the creation of a strong Allee effect. The result is the survival of the population in a case when it would go extinct without cannibalism. (Received September 11, 2013)

1096-92-911 **Heather A. Harrington***, Mathematical Institute, Radcliffe Observatory, Woodstock Road, Oxford, OX2 6GG, United Kingdom, and **Kenneth L. Ho**, **Nicolette Meshkat**, **Paul Kirk**, **Thomas Thorne** and **Michael P.H. Stumpf**. *A parameter-free framework for model discrimination using algebraic geometry, differential algebra, statistics and data.*

In many branches of science, one is often interested in the problem of model selection: given observed data and a set of candidate models for the process generating the data, which is the best? In this talk, I will present a procedure for deciding when a special class of polynomial dynamical systems (mass-action) is incompatible with observed data and may be useful for discarding a model framework that is not capable of producing observed behavior.

The key idea uses ideas from algebraic geometry to construct a transformation of the model variables such that any set of steady states of the model under that transformation lies on a common plane, irrespective of the values of the model parameters. This method is based only on model structure and is independent of kinetic parameter values, hence parameter-free. We demonstrate our method by applying it to protein signaling.

Finally, we present preliminary work that extends our method to include dynamics (i.e. time-course data), which relies on differential algebra elimination and Gaussian processes. This general framework complements conventional statistical methods in certain classes of problems, and furthermore, coplanarity can serve as a fast preprocessor for models before optimization. (Received September 11, 2013)

1096-92-951 **Jesse W Drendel**, **Michael F Antolin** and **Daniel J Bates*** (bates@math.colostate.edu), CSU Department of Mathematics, 101 Weber, Fort Collins, CO 80523-1874, and **Patrick D Shipman** and **Simon J. Tavener**. *Linkage disequilibrium between independently assorting loci, via numerical algebraic geometry.*

In population genetics, linkage disequilibrium is the occurrence of clusters of genes in a population more often (or less often) than expected, based on allele frequencies in the population. Linkage disequilibrium has been observed in reality, but the standard models in population genetics (particularly that of Lewontin and Kojima) do not allow for linkage disequilibrium in the case of independent assortment. However, in order to make calculations feasible, such models make the assumption that homozygotes are equally fit, which is not necessarily the case. By generalizing the model of Lewontin and Kojima to allow homozygotes to have different fitnesses, we arrive at a model for which linkage disequilibrium is feasible under independent assortment.

In this talk, I will define much of what is said in the previous paragraph, provide a short (new) proof that there are no more than 15 equilibria with 2 alleles at each of 2 loci, and show how numerical algebraic geometry led us to the discovery of this generalized model with linkage disequilibrium under independent assortment. (Received September 11, 2013)

1096-92-975 **SUZANNE LENHART*** (lenhart@math.utk.edu), University of Tennessee, Math Dept. 227 Ayres Hall, KNOXVILLE, TN 37996-1320. *Optimal control in models of management of forest resources.* Preliminary report.

Optimal control theory can be used to choose management strategies in models in involving sustainability of a resource population. An example model of harvesting non-timber forest products will be given. A second example will model the use of a pathogen to slow an invasion of gypsy moths on tree populations. (Received September 11, 2013)

1096-92-1142 **Ruth Davidson*** (redavids@ncsu.edu), 108 West Stinson Street, Chapel Hill, NC 27516, and **Seth Sullivant**. *Polyhedral geometry of distance-based phylogenetic methods.*

A phylogenetic tree models the common evolutionary history of a set of species. A tree metric is a distance function on a set of species realized by pairwise path distances between the leaves of a phylogenetic tree with edge weights. Distance-based phylogenetic methods map an arbitrary dissimilarity map representing biological data to a tree metric. The set of all dissimilarity maps is a Euclidean space containing as a subset the space of all tree metrics, which is a polyhedral fan and a tropical variety. We study the behavior of distance-based tree reconstruction methods such as UPGMA, Neighbor-Joining, Least-Squares Phylogeny, and Balanced Minimum Evolution using the polyhedral geometry of the subdivision of Euclidean space induced by the methods. (Received September 13, 2013)

1096-92-1170 **Artem S. Novozhilov*** (artem.novozhilov@ndsu.edu), North Dakota State University, Mathematics Dept #2750, Attn: Melanie, PO Box 6050, Fargo, ND 58108, **Yuri Semenov**, Applied Mathematics–1, Moscow State University of Railway Engineerin, Moscow, 127994, Russia, and **Alexander Bratus**, Lomonosov Moscow State University, Computational Mathematics and Cybernetics, Moscow, 119992, Russia. *Linear algebra of the Crow-Kimura quasispecies model.*

The Crow-Kimura quasispecies model with permutation invariant fitness landscape is a famous 'almost linear' system of ODEs, for analysis of which intricate methods of classical and quantum mechanics, statistical physics, and elaborate numerical algorithms were applied. Our approach to this problem is to use the standard methods of linear algebra. Using the fact that the mutation matrix in the case of permutation invariant fitness landscape has a special form, a change of the basis is found such that in new coordinates a number of analytical results can be obtained. In particular, we show that if the mutation rate approaches infinity, the quasispecies distribution always tends to the uniform one; hence the notorious error threshold is actually inherent in this weaker sense in any quasispecies model. A parametric solution to the system of equation determining the quasispecies is found; this parametric solution allows obtaining a new heuristic formula for the error threshold. We propose a rigorous mathematical definition of the closeness of the quasispecies to the uniform distribution, which can be used as an operational definition of the error threshold. Using this definition, we find another approximate formula to estimate the critical mutation rate for the error threshold. (Received September 13, 2013)

1096-92-1185 **Romuald N. Lipcius*** (`rom@vims.edu`), **Leah B. Shaw**, **Junping Shi**, **Jian Shen** and **Allison M. Colden**. *Synergy of Mathematical Modeling and Ecology in Native Oyster Restoration.*

Native oyster populations have been depleted worldwide, leading to large-scale restoration efforts, which have failed until recently. One cause of the failure has been the lack of comprehensive population models linked to ecological experiments that produce realistic parameter estimates and process functions. We have developed a system of ordinary differential equations with three state variables, oyster biomass, reef volume, and sediment volume, which portray the nonlinear dynamics of the system. Predictions from the model have (i) generated novel hypotheses about oyster population dynamics, including the potential for alternative stable states and spatial self-organization, (ii) been used to inform multi-million dollar native oyster restoration efforts in Chesapeake Bay, and (iii) been tested with complementary field experiments that examine model predictions and in turn produce reliable parameter estimates and process functional forms. We discuss the value and provide specific examples of the integration of mathematical modeling and ecological experiments for effective native oyster restoration. (Received September 13, 2013)

1096-92-1191 **Martha Bauver***, Department of Mathematical Sciences, Montclair State University, 1 Normal Avenue, Montclair, NJ 07043, **Lora Billings**, Department of Mathematical Sciences, Montclair State University, 1 Normal Avenue, Montclair, NJ 07043, and **Eric Forgoston**, Department of Mathematical Sciences, Montclair State University, 1 Normal Avenue, Montclair, NJ 07043. *Using FTLEs to Find Optimal Extinction Paths in Stochastic Population Models.*

We consider a variety of stochastic population models, including a bistable model that switches between two steady states. Using finite time Lyapunov exponents (FTLEs), we numerically find the optimal path, which is the path that maximizes the probability of extinction. We verify our numerics with analytical results found using large fluctuation theory. We also will discuss the use of FTLE maps as an effective tool for determining the optimal path in higher dimensional systems where no analytical result exists. (Received September 13, 2013)

1096-92-1193 **Michael Morley***, Department of Mathematical Sciences, Montclair State University, 1 Normal Avenue, Montclair, NJ 07043, **Lora Billings**, Department of Mathematical Sciences, Montclair State University, 1 Normal Avenue, Montclair, NJ 07043, and **Eric Forgoston**, Department of Mathematical Sciences, Montclair State University, 1 Normal Avenue, Montclair, NJ 07043. *Simulating Bistable Population Models.*

We consider a class of bistable stochastic population models with the goal of predicting the rare occurrence of extinction. In simulations, we observe switching between the steady states before an extinction event, which we refer to as cycling. Using probabilistic methods and large fluctuation theory we derive how cycling impacts the mean time to extinction. We compare our analytical results to Monte Carlo simulations for verification. We also discuss the limitations of this theory and derive other statistics from the data. (Received September 13, 2013)

1096-92-1194 **Jamila Haramuniz***, Department of Mathematical Sciences, Montclair State University, 1 Normal Avenue, Montclair, NJ 07043, **Lora Billings**, Department of Mathematical Sciences, Montclair State University, 1 Normal Avenue, Montclair, NJ 07043, and **Eric Forgoston**, Department of Mathematical Sciences, Montclair State University, 1 Normal Avenue, Montclair, NJ 07043. *Stochastic Modeling and Control of a Population.*

We consider extinction in a stochastic model of a population. The extinction may be delayed if there are multiple steady states in the system. The population may repeatedly switch between the steady states before extinction, a behavior which we call cycling. To decrease the time to extinction, we add the random removal of individuals from the population as a control method. We analytically quantify the effect of cycling and control on the mean time to extinction by probabilistic methods and large fluctuation theory. These results were compared to Monte Carlo simulations for verification. (Received September 13, 2013)

1096-92-1240 **Marc A Harper*** (`marcharper@ucla.edu`). *The Inherent Randomness of Evolving Populations.*

Entropy rates are measures of the variation dependent on both short-run and long-run behavior, and allow the relationships between mutation, selection, and population size in biological models to be examined. The entropy rates of the Wright-Fisher process, the Moran process, and generalizations are computed and used to compare these processes and their dependence on standard evolutionary parameters. Analytic results are possible in many cases and strict upper bounds for the entropy rate are given for the Moran process (independent of population size) and for the Wright-Fisher process (bounded for fixed population size). A generational Moran process is also presented for comparison to the Wright-Fisher Process. Results include analytic results and computational extensions. (Received September 13, 2013)

1096-92-1251 **Lih-Ing W. Roeger*** (lih-ing.roeger@ttu.edu), Department of Mathematics and Statistics, Box 41042, Texas Tech University, Lubbock, TX 79409-1042, and **Sze-Bi Hsu**. *Competition of Two Species for Two Limited Resources with One Species Mediated by Parasites.* Preliminary report.

A mathematical model of two host species competing for two limited resources with one of the species mediated by parasites is considered. The first host species is divided into the susceptible and the infective population. The second species is assumed to be free of infection and is not able to get infected. We analyze the system of four differential equations by finding the conditions for the existence of the various equilibria and their local stability criteria. (Received September 13, 2013)

1096-92-1277 **Faina Berezovskaya*** (fberezovskaya@howard.edu), 6 str., Washington, DC 20059. *Effect of predators in dynamics of niche construction.*

In this paper a question of "how much overconsumption a renewable resource can tolerate" is addressed using a mathematical model, where a consumer population that compete for the common resource and can also contribute to resource restoration , is subject to an attack of predators. Through bifurcation analysis we show that well-adapted predators can keep the system in a stable equilibrium even for "strong" overconsumption, so, extending domain of system sustainability. We introduce a measure of prey adaptation depending on other parameters of the model and compare dynamics of the models without- and with- predators. It was also observed that for some parameter domains a population can survive or go to extinct depending on its initial conditions. (Received September 14, 2013)

1096-92-1303 **Robert Stephen Cantrell***, Department of Mathematics, The University of Miami, Coral Gables, FL 33124, and **Daniel Ryan**. *Avoidance behavior in intraguild predation communities: A cross-diffusion model.*

A cross diffusion model of an intraguild predation community where the intraguild prey employs a fitness based avoidance strategy is examined. The avoidance strategy employed is to increase motility in response to negative local fitness. Global existence of trajectories and the existence of a compact global attractor is proved. It is shown that if the intraguild prey has positive fitness at any point in the habitat when trying to invade, then it will be uniformly persistent in the system if its avoidance tendency is sufficiently strong. This type of movement strategy can lead to coexistence states where the intraguild prey is marginalized to areas with low resource productivity while the intraguild predator maintains high densities in regions with abundant resources, a pattern observed in many real world intraguild predation systems. Additionally, the effects of fitness based avoidance on eigenvalues in more general systems are discussed. (Received September 14, 2013)

1096-92-1372 **Robert Stephen Cantrell** and **Chris Cosner*** (gcc@math.miami.edu), Department of Mathematics, University of Miami, Coral Gables, FL 33124, and **Yuan Lou** and **Daniel Ryan**. *Evolutionary stability of ideal free dispersal in spatial population models with nonlocal dispersal.*

An important problem in the study of the evolution of dispersal is determining what kinds of dispersal strategies are evolutionarily stable. A class of strategies that have been shown to be evolutionarily stable in various contexts are those that produce an ideal free distribution of the population, that is, a spatial distribution where no individual can increase its fitness by moving to another location. This talk will present results on the evolutionary stability of ideal free dispersal strategies in the context of continuous time nonlocal dispersal models. These results partially extend some recent work on the evolutionary stability of ideal free dispersal for reaction-advection-diffusion equations and discrete diffusion models to nonlocal dispersal models. They also include an extension of an inequality from matrix theory to the case of nonlocal dispersal operators, which may be of independent interest. (Received September 15, 2013)

1096-92-1549 **Maria A. Corsaro*** (mcorsaro@nd.edu), 803 Cottonwood Drive, Malvern, PA 19355, and **Dan Anderson** and **Padmanabhan Seshaiyer**. *Modeling the Human Tear Film during a Blink while Wearing a Contact Lens.* Preliminary report.

Millions of people worldwide wear contact lenses. The presence of a contact lens on the eye changes the behavior of the human tear film. This relationship is examined during the period of the blink when the upper eyelid is opening. A model is created through the use of standard thin film assumptions and is then reduced to a nonlinear partial differential equation for the thickness of the tear film. Two different models for the lipid layer are also incorporated into the model. A numerical solution to the partial differential equation is calculated using the method of lines to discover the shape of the tear film for the specific set of conditions being explored. There are still several variables that remain to be calculated in order to produce accurate results to answer this research question. However, it is possible to compute solutions describing the initial and final tear film height for the case where the upper eyelid is stationary and there is no contact lens. This proof-of-concept test successfully demonstrates that this model is able to accurately represent these cases. It is therefore logical that the next step in the development of this model is to estimate these remaining parameters so that results can be produced that reflect the desired situation. (Received September 16, 2013)

1096-92-1581 **Nairat Kanyamee*** (nairat@su.ac.th), Department of Mathematics, Faculty of Science, NaKhon Pathom, 73000. *Mathematical Model of Infection Risk to Travelers Entering Malaria Endemic Regions.*

In this work, we study the Malaria infection risk when travelers are visiting or entering a Malaria endemic region. A simple mathematical model of **S**usceptible-**I**nfected-**S**usceptible (**SIS**) containing six non-linear differential equations is formulated to describe the transmission of Malaria in an endemic region. We analyzed the system by using a standard dynamical method for the system of differential equations. The conditions for equilibrium are obtained by considering the possibility of zeros of a third degree polynomial. The numerical result demonstrates the number of travelers as well as the behavior to the equilibrium of those who become infected with Malaria after entering an endemic region. (Received September 16, 2013)

1096-92-1617 **Elizabeth L Councill*** (emartin@rsmas.miami.edu). *Modeling the Effects of Age-Specific Harvesting on Connected Subpopulations of Marine Fish Using a Discrete Age Continuous Time Approach.*

The impacts on population structure of variability in spawning behaviors and fishing mortality rates among connected subpopulations of marine fish are not well understood. This paper presents a new discrete age continuous time modeling approach for investigating these impacts on a connected two-subpopulation system of an exploited marine fish species. By comparing the solutions of this model under different age-structured fishing mortality patterns, it is possible to evaluate how these differences manifest at the population level. A derivation and analysis of the model are presented as well as an application to the ontogenetic migration of Atlantic Tarpon, *Megalops atlanticus*. (Received September 16, 2013)

1096-92-1654 **Antonio Mastroberardino***, axm62@psu.edu, and **Yuanji Cheng**, **Ahmed Abdelrazec** and **Hao Liu**. *Mathematical Modeling of the HIV/AIDS Epidemic in Cuba.* Preliminary report.

In this talk, I will present a nonlinear mathematical model for the transmission dynamics of HIV/Aids in Cuba. Due to Cuba's highly successful national prevention program, we assume that the only mode of transmission is through contact with people who do not know that they are HIV positive. We find the equilibria of the governing nonlinear system, perform a linear stability analysis, and then determine the threshold for global stability. We conclude with an application of optimal control as a demonstration of the effectiveness of the Cuban prevention program. (Received September 16, 2013)

1096-92-1789 **Jack Quine** (quine@math.fsu.edu) and **Yuanting Lu*** (lu_y@mercer.edu). *Exploring the Uniformity of Transmembrane Alpha-helix.*

Transmembrane alpha-helices have been experimentally shown to be uniform in structure due to the low dielectric environment. The hydrogen bond geometry, peptide plane tilt angles, and backbone torsion angles are all more conserved. We mathematically explore the uniformity by checking the connection between backbone torsion angles and hydrogen bond distances. We find the backbone torsion angles tend to distribute uniformly as the hydrogen bond distances are optimized. We also explore the connection between hydrogen bond angles and hydrogen bond distances. Discrete Frenet frame is used as an effective tool to study the helical backbone structure. (Received September 16, 2013)

1096-92-1798 **Nora Youngs*** (s-nyoungs1@math.unl.edu), Department of Mathematics, 203 Avery Hall, Lincoln, NE 68588-0130, and **Carina Curto**, **Vladimir Itskov** and **Alan Veliz-Cuba**. *The Neural Ring: An Algebraic Tool for Analyzing the Intrinsic Structure of Neural Codes.*

Neurons in the brain represent external stimuli via neural codes. These codes often arise from stereotyped stimulus-response maps, associating to each neuron a convex receptive field. An important problem confronted by the brain is to infer properties of a represented stimulus space without knowledge of the receptive fields, using only the intrinsic structure of the neural code. How does the brain do this? To address this question, it is important to determine what stimulus space features can – in principle – be extracted from neural codes. This motivates us to define the neural ring and a related neural ideal, algebraic objects that encode the full combinatorial data of a neural code. Our main finding is that these objects can be expressed in a "canonical form" that directly translates to a minimal description of the receptive field structure intrinsic to the neural code. We also find connections to Stanley-Reisner rings, and use ideas similar to those in the theory of monomial ideals to obtain an algorithm for computing the primary decomposition of pseudo-monomial ideals. This allows us to algorithmically extract the canonical form associated to any neural code, providing the groundwork for inferring stimulus space features from neural activity alone. (Received September 16, 2013)

1096-92-1801 **Shannon Stock***, 170 Brookline Ave, UNIT 327, Boston, MA 02215, and **Victor DeGruttola**. *Two-Sample Tests and Recursive Partitioning with Latent Responses: Application to HIV Genetics.*

Clinical studies evaluating the efficacy of antiretroviral therapy in suppressing human immunodeficiency virus replication frequently use viral rebound to clinically indicate treatment failure. However, since viral load measurements are measured with error, there may be uncertainty regarding whether an observed increase in viral load is due to such error or to viral rebound. Therefore, analyses of such studies must accommodate a response that is not directly observable. In this paper we present a recursive partitioning method for a latent event that estimates the probability of occurrence of an event between successive (in time) pairs of observations, given an observed change in outcome measurements. The only required parametric assumptions relate to the estimation of the outcome measurements' error distribution. We evaluate the performance of our method using simulation studies, and provide an application based on HIV viral genetic data from the AIDS Clinical Trials Group 398 clinical study. (Received September 16, 2013)

1096-92-1816 **Angela L Peace*** (angela.peace@asu.edu) and **Yang Kuang**. *A stoichiometric producer-grazer model incorporating the effects of excess food-nutrient content on consumer dynamics.*

There has been important progress in understanding ecological dynamics through the development of the theory of ecological stoichiometry. For example, modeling under this framework allows food quality to affect consumer dynamics. While the effects of nutrient deficiency on consumer growth are well understood, recent discoveries in ecological stoichiometry suggest that consumer dynamics are not only affected by insufficient food nutrient content (low phosphorus (P): carbon (C) ratio) but also by excess food nutrient content (high P:C). This phenomenon is known as the stoichiometric knife edge, in which animal growth is reduced not only by food with low P content but also by food with high P content, and needs to be incorporated into mathematical models. Here we present Lotka-Volterra type models to investigate the growth response of Daphnia to algae of varying P:C ratios capturing the mechanism of the stoichiometric knife edge. (Received September 16, 2013)

1096-92-1827 **Rebecca A. Everett*** (rarodger@asu.edu), Arizona State University, 901 S Palm Walk, Department of Mathematics, Tempe, AZ 85287-1804, and **Yang Kuang**. *Predicting the time and mechanism for resistance in prostate cancer patients undergoing androgen suppression therapy.*

Prostate cancer is the most common non-skin cancer in men and second most fatal in the United States. It is often treated by a hormone therapy called androgen suppression therapy since both normal and cancerous prostate cells depend on androgens for growth and survival. Due to the side effects of this treatment, the quality of life decreases for the patients while on the therapy. Thus patients often choose intermittent androgen suppression therapy (IAS), in which the patients alternate between durations of on and off treatment. However, the timing for the switching is dependent upon the doctor's experience and intuition. Using a mathematical model, we predict whether or not a patient can undergo another off treatment cycle and test this prediction with clinical data. We use our mathematical model to predict the time and the main mechanisms for the development of resistance to androgen suppression therapy for each patient. Clinically, this can become an important tool for determining the appropriate treatment option for individual patients. (Received September 16, 2013)

1096-92-2059 **Rene A. Salinas*** (salinasra@appstate.edu), Department of Mathematical Sciences, 342 Walker Hall, Boone, NC 28608. *Modeling the Impact of Food Availability on Disease Spread in Feral Hogs.* Preliminary report.

The population dynamics of feral hogs in Great Smoky Mountains National Park are driven primarily by annual fall hard mast variation. It has been well documented that this variation can impact movement and reproductive success. An additional impact that has not been well studied is disease spread. I will use an individual-based model to analyze the impact of fall hard mast variation on the spread of pseudorabies virus in feral hogs. Results suggest that although mast failures can cause individuals to move greater distances, it can also cause small clusters of hogs in specific forest patches. This mix of dispersing and clustering leads interesting disease dynamics. (Received September 17, 2013)

1096-92-2070 **Amanda J Mangum*** (`asmith5@ncsu.edu`), Biomathematics Graduate Program, Box 8205, NC State University, Raleigh, NC 27695, and **Mansoor A Haider** (`m_haider@ncsu.edu`), Dept. of Mathematics, Box 8205, NC State University, Raleigh, NC 27695. *Data clustering algorithms for ultrasound imaging of atherosclerotic plaques.*

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 to ensure that neighboring data clusters are more similar than clusters far away from each other (in terms of the map topology). Several examples that illustrate and evaluate the effectiveness of SOM-based data clustering techniques in ARFI imaging of atherosclerotic plaques are presented. (Received September 17, 2013)

1096-92-2085 **Shelby N. Wilson*** (`shelby.wilson@gmail.com`). *Mathematical Modeling of Adaptive Immune Regulation.*

It is widely accepted that the primary immune system contains a subpopulation of cells, known as regulatory T cells (Tregs) whose function is to regulate the magnitude of the immune response. Recent experiments have highlighted a phenomenon known as "Treg Switching", wherein regulatory T cells lose their immunoregulatory function and transition into immunostimulatory cells. Here, we develop mathematical models to investigate the effects of Treg switching on the immune response. We consider this mechanism both in the context of a simple, ordinary differential equation (ODE) model and in the context of a more biologically detailed, delay differential equation (DDE) model of the primary immune response. Both models express the usual characteristics of an immune response with the added capabilities of being able to correct for initial imbalances in T cell populations. We also observe an increased robustness of the immune response with respect to key parameters. (Received September 17, 2013)

1096-92-2086 **Shelby N. Wilson*** (`shelby.wilson@gmail.com`). *Maximizing anti-tumor effects in combination drug therapy.*

Anti-angiogenic drugs – drugs that restrict the creation of new blood vessels– have recently become of particular interest in the quest to cure cancer. Despite immense research dedicated to the topic, the effects of such drugs are complex and not well understood. In order to maximize their therapeutic benefits, the dynamics of anti-angiogenic drugs must be understood. As such, we have developed a non-linear, mixed-effect ODE model as a strategy to quantify the dynamics of tumor growth, vasculature generation, chemotherapy, and anti-angiogenic treatment. Model parameters are estimated in a mixed-effect fashion using the SAEM (Stochastic Approximation of the Expectation Maximization) algorithm. This model accurately predicts tumor growth dynamics of colorectal tumor growth data and allows us to study the multifaceted effects of anti-angiogenic treatment. (Received September 17, 2013)

1096-92-2133 **Jeremy N Ariche*** (`jeariche@gmail.cm`), 13610 NC Hwy 94 N, Creswell, NC 27928. *Precise Mass Measurements of Ions.*

One essential feature of the Low Energy Beam and Ion Trap (LEBIT) Facility is the laser ablation source (LAS) system. Comprised of a laser source, extraction system, three electrostatic quadrupoles, and an ion target, the system use the photoelectric effect to ablate charged particles from the target and guide it into the beam line for mass measurements. To achieve optimization, various parts of the contraption must be altered via system tuning. The process normally involves adjusting the voltages of various electrodes and monitoring the resulting behavior of the ions until they behave in a desired manner. Recently, the location of the gate valve has been changed which affected distance between the position of the extraction system and quadruple deflectors. This in turn will negatively affect the total efficiency of the ion beam source passing into the line because not all ions pass through the system. In order to resolve this problem, a simulation program, called SIMION, is used. Through the program, we aim to update the configuration of parts within LAS system and discover the optimum settings for focusing the trajectory and guiding it to its destination. From these settings, we can begin to take more reliable measurements for the Q-value of 96Zr. (Received September 17, 2013)

1096-92-2320 **Neal Williams*** (nfwilli2@asu.edu). *De Bruijn Graph Analysis of Transposable Elements in DNA.*

The recent availability of inexpensive, short-read DNA sequencing data has created the need for algorithms that can efficiently assemble this data into contiguous genomic sequences. Many popular assemblers utilize a De Bruijn graph structure that represents each sequence of length k as a separate node in the assembly graph and connects nodes with sequences that overlap by $k-1$ nucleotides with directed edges. This assembly problem is confounded by the existence of transposable elements (TEs), which are potentially highly-repetitive DNA sequences that are able to reinsert themselves into the genome at different loci. The TE profiles for eukaryotes can vary widely between species, which suggests a volatile evolutionary history that is only partially understood. We have implemented an algorithm that finds DNA sequences that align to the consensus sequence for known TE families, and then uses this data to construct De Bruijn assembly graphs which can be visualized to aid interpretation. In the talk, we will explore what insights this approach reveals about the complexities that TE families induce in complete assembly graphs, the effectiveness of long read data in reducing assembly graph complexity, and the TE variation observed across different tissues, organisms, and species. (Received September 17, 2013)

1096-92-2355 **Lester F. Caudill*** (lcaudill@richmond.edu), Department of Mathematics & Computer Science, 28 Westhampton Way, Univ. of Richmond, VA 23173. *Mathematical Models in Medicine.*

We present two examples of final projects used in the course "Mathematical Models in Biology and Medicine" at the University of Richmond. The first involves modeling the growth of a cancerous tumor and the effects of radiation therapy. The second involves the interaction of two strains of bacteria – differing in their susceptibility to a particular antibiotic, and the subsequent impact of varying levels of use of that antibiotic. (Received September 17, 2013)

1096-92-2375 **Lester F. Caudill*** (lcaudill@richmond.edu), Department of Mathematics & Computer Science, 28 Westhampton Way, Univ. of Richmond, VA 23173, and **Barry Lawson**. *A Hybrid Model of Hospital Infection Spread.*

Serious infections due to antibiotic-resistant bacteria are pervasive, and of particular concern within hospital units due to frequent interaction among health-care workers and patients. Such nosocomial infections are difficult to eliminate because of inconsistent disinfection procedures and frequent interactions among infected persons, and because ill-chosen antibiotic treatment strategies can lead to a growth of resistant bacterial strains. Clinical studies to address these concerns have several issues, but chief among them are the effects on the patients involved. Realistic simulation models offer an attractive alternative. This paper presents a hybrid simulation model of antibiotic resistant infections in a hospital ward, combining agent-based simulation to model the inter-host interactions of patients and health-care workers with a detailed differential equations and probabilistic model of intra-host bacterial and antibiotic dynamics. Initial results to benchmark the model demonstrate realistic behavior and suggest promising extensions to achieve a highly-complex yet accurate mechanism for testing antibiotic strategies. (Received September 17, 2013)

1096-92-2458 **Eric Alan Eager*** (eeager@uwlax.edu), 1725 State Street, La Crosse, WI 54601, and **Anita Davelos Baines** and **Andrew M. Jarosz**. *Modeling and Analysis of Fungus-Infected American Chestnut Populations.*

Chestnut blight is a classic example of how introduced pathogens can alter host population biology and overall plant community dynamics. The blight pathogen *Cryphonectria parasitica*, introduced throughout the American chestnut populations in the 1900s, has caused a rapid, large-scale die-off of this important tree species throughout much of the United States. Only the introduction of an intracellular hyperparasite of *C. parasitica* has been able to halt the expansion of the fungus-infected cankers that eventually kill the chestnut trees, but the long-term robustness of this recovery is still an open ecological question.

We developed structured population models to assess how changes in fungus and hypovirus infection influence the short and long-term population dynamics of American chestnut trees in the Upper Peninsula of Michigan, and use the results of these models to provide conservation suggestions. Specifically, we show that hypovirus introduction can cause a significant 50-year transient amplification followed by (previously unexpected) asymptotical population decline. This suggests that hypovirus introduction alone is not sufficient to save the American chestnut population. (Received September 17, 2013)

1096-92-2480 **Hayriye Gulbudak*** (hgulbudak@ufl.edu). *A Structured Avian Influenza Model with Imperfect Vaccination.*

Vaccination of poultry is an important control strategy for avian influenza. In general, vaccination does not induce perfect immunity in populations, instead producing partial protection by reducing the probability of infection and decreasing the severity of infection. We introduce a model of avian influenza in domestic birds with imperfect vaccination and age-since-vaccination structure to account for variable waning of the partial protection. The basic reproduction number, $\mathcal{R}_0$, is calculated. The disease-free equilibrium is found to be globally stable when $\mathcal{R}_0 < 1$ under certain conditions. When $\mathcal{R}_0 > 1$, existence of an endemic equilibrium is proved (with uniqueness for a special case), and uniform persistence of the disease is established. The inclusion of both mechanisms of partial protection from vaccination can have important implications for disease control. We analytically and numerically demonstrate that vaccination can paradoxically increase the total number of infected, resulting in the "silent spread" of the disease. We also study the combined impact of increasing vaccine efficacy and vaccination coverage on $H5N1$ AI disease control. (Received September 17, 2013)

1096-92-2525 **Matthew V. Cattivera*** (mcattivera@sandiego.edu), **Seth D. Haney** and **Adam Siepielski**. *A perturbation approach to approximate extinction time in ecological systems due to harsh conditions.* Preliminary report.

Changes in the environment can have an effect on the stability of ecological communities. Further, harsh environmental conditions can prompt the extinction of vulnerable species. How can we determine how long it takes for a species to go extinct given harsh environmental conditions? Here, we use the classic Lotka-Voltera competition model to study this problem. The Lotka-Volterra model is an unsolvable ODE system; however, in the particular case of ecological equivalence (where competing species have equal competition coefficients and growth rates) it is only the sum of the species that is regulated and the system can be solved exactly when no environmental fluctuations are present. Under the assumption that the environment has a small effect on the dynamics of the species, we use a perturbation method to approximate analytical solutions to extinction time given harsh or favorable environmental conditions. (Received September 17, 2013)

1096-92-2549 **Seth D. Haney*** (shaney@sandiego.edu) and **Adam Siepielski**. *Effects of Stochastic Variation in Resource Availability in Ecological Community Structure.*

Stochastic effects can fundamentally change the outcome of systems in competition. In ecological competition systems, stochastic variability plays a critical, yet not well understood, role in structuring community dynamics. Here we analyze the boundary between niche-structured communities and neutrally-structured communities by allowing two species that are ecologically neutral to have rare access to specialized resources. We model this competition system by constructing Chemical Master Equation, that we solve numerically using the Gillespie Exact Stochastic Simulation Algorithm. We find that rare resources can provide large benefits, on average, to the stability of coexistence in these competition systems. However, we also find, surprisingly, that rare resources can act to destabilize coexistence if the rare resources appear at inopportune times. We also use our model to investigate the likelihood that an experimental ecologist would be able to resolve the difference between competition systems with rare niches and non-niche differentiated systems (neutral dynamics). We show that stochastic variability imposes decidedly larger experimental constraints than are currently commonplace in experimental methodology. (Received September 17, 2013)

1096-92-2566 **Mohammed Yahdi*** (myahdi@ursinus.edu), Depart of Mathematics & Computer Science, Ursinus College, Collegeville, PA 19426, and **Hongli Chen**, Department of Mathematics & Computer Science, Ursinus College, Collegeville, PA 19426. *Mathematical Model of Carbapenem-Resistant Enterobacteriaceae with Prevalence Settings.* Preliminary report.

The treatment of drug-resistant bacterial infections can become a global crisis due to the emergence of stronger antimicrobial resistance, and the scarcity of new antibiotics. More than two million people in the US become infected with antibiotic resistant bacteria, specially deadly and costly to ICU patients with vulnerable immune system. The infections caused by carbapenem-resistant Enterobacteriaceae (CRE), on the rise and designed by CDC as urgent infections, have been associated with high mortality in ICUs (up to two third), and have demonstrated resistance to the strongest antibiotics. Therefore, with limited treatment options, this project's aims include the use mathematical modeling tools to understand and simulate the mechanism underlying the spread of CRE in ICUs, and determine efficient and cost effective control strategies that incorporate special preventive measures. The dynamic model includes CRE susceptible, contaminated and infected patients, with low and high CRE risk and prevalence categories, as well as twenty-three independent parameters derived from research and clinical data. The model is distinctive by incorporating special preventive measures that have shown to significantly reduce infections and clear contaminations for other antimicrobial infections. (Received September 17, 2013)

1096-92-2706 **Leonila Lagunes*** (leo.lagunes13@gmail.com), 2627 N. Bourbon st apt 43, Orange, CA 92865, and **Charles H Lee** (charleshlee@fullerton.edu), 800 N. State College Blvd., Fullerton, CA 92831. *Cancer Screening Using Biomimetic Pattern Recognition with Hyper-Dimensional Planar Structures.*

Biomimetic Pattern Recognition (BPR) is a technique that creates a hyper-dimensional (HD) geometric body by mimicking a biological system and uses it for classification. BPR is derived from the Principle of Homology-Continuity (PHC), which assumes members of the same class are connected by means of gradual evolution. Recently, we introduced a new approach to the PHC, where elements of the same class were connected via HD line segments. In this research, we propose a new BPR technique where elements are connected via HD planes and thus there exist multiple ways to construct and connect alike members. In our case, we consider three different distance calculation techniques and three different extension methods when constructing a BPR structure. The resulting biological organisms are more complicated and the mimicking process becomes computationally intensive. When found, these structures represent the core of a class and provide a basis for classification of an arbitrary node. Elements of the test sets are classified based on their proximities relative to structures. We investigate the effect of different distance calculation and extension methods on the overall accuracy. Results based on DNA microarray data for Leukemia and Colon cancers are also discussed. (Received September 18, 2013)

1096-92-2716 **Jason E Miller*** (jason.miller@csuci.edu), One University Dr, Camarillo, CA 93012. *Relative critical sets, medial axes, and networks.*

Teaching computers how to see shapes in a digital image is a challenge whose solution varies by context. The medial axis transform provides a rich and elegant way to describe shapes in binary images. An attempt to extend that idea to greyscale images led to Eberly's height ridge and scale-space ridge and Damon's relative critical set. The generic structure of these sets has been classified, but attempts to realize them as a generalization of the medial axis have not been successful. This talk will describe these sets and attempts that have been made to use relative critical sets as proxy for medial axes is greyscale images. (Received September 18, 2013)

1096-92-2739 **Anca R Radulescu*** (radulesc@colorado.edu), 395 UCB, Department of Mathematics, University of Colorado at Boulder, Boulder, CO 80309-0395. *Effects of connectivity on dynamic behavior in neural networks.*

The study of dynamic networks has been the focus of great interest in recent research. Many natural systems are organized as networks, in which the nodes interact in a time-dependent fashion. It has been hypothesized that there are two key conditions for optimal function in such networks: a well-balanced adjacency matrix and well-balanced connection strengths, driving optimal dynamics in the system. The object of our study is relating connectivity to the temporal behavior of the network. We consider an n-dimensional dynamical system, in which variables are nonlinear oscillators, coupled according to a connectivity scheme that obeys certain constrains, but also incorporates random aspects. We study how the phase space dynamics and bifurcations of the system change when perturbing the underlying adjacency graph.

Understanding the effects of configuration on coupled dynamics is of great importance for a wide variety of applications. Recent studies have used a combination of dynamical systems and graph theoretical approaches to investigate general organizational principles of brain networks. We will illustrate how these approaches may be used to better understand neural processes, or even to obtain biomarkers for behavioral traits or neuropsychiatric conditions. (Received September 18, 2013)

1096-92-2784 **Monica Nicolau*** (mkl@ams.org). *Geometry and topology in cancer systems biology.*

Examples of geometric and topological data analysis in cancer systems biology. Topological data analysis is used to analyze breast cancer transcriptional data and identify a unique subgroup of Estrogen Receptor-positive (ER+) breast cancers with excellent survival prognosis. A geometric approach to high dimensional data analysis called disease-specific genomic analysis (DSGA) will be discussed. (Received October 15, 2013)

93 ► Systems theory; control

1096-93-198 **Michael Malisoff*** (malisoff@lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803-4918. *Tracking Problems for Marine Robots with Input Delays: A Case Study in Feedback Control.*

Given a dynamical system, the control problem entails choosing values for a set of parameters of the system, in order to achieve some desired behavior for all or some of the trajectories. When the parameters depend on the state of the system and time, we call the parameters feedback controls. Feedback controls are ubiquitous in engineering. However, current values of the state of the system might not be available for measurement. Instead, the controls are functions of time and old values of the state. When this occurs, we say that the system has input delays. This talk presents a case study in feedback control for marine robot models with input delays, where there are also constraints on the allowable values of the states, as well as uncertainties in the system. The control objective is for the robots to track a desired three dimensional reference trajectory. Our main theoretical tools are Lyapunov-Krasovskii functionals and robust forward invariance. This is joint work with Fumin Zhang from the Georgia Tech School of Electrical and Computer Engineering. (Received August 15, 2013)

1096-93-311 **Dylan R Poulsen*** (dylan_poulsen@baylor.edu), Waco, TX, and **John M Davis** and **Ian A Gravagne**. *Stability of Markov Chains: A Time Scales Viewpoint with Applications to Control.*

We present a version of Lyapunov theory for discrete time scales where the distances between time scale points are independent random variables.

In the case of quadratic Lyapunov functions for the LTI case, our results improve the requirement that $spec(A) \subset \mathcal{H}_{\min}$, the smallest Hilger circle. Through this analysis, we encounter an interesting geometric relationship between the regions of almost sure exponential stability and stochastic Lyapunov stability. Specifically, the region of stochastic Lyapunov stability is the osculating circle to the region of almost sure exponential stability.

Our approach also allows us to consider a special class of LTV problems where the dependence on time is only through the distance between adjacent time scale points. As an application of these results, we consider observer-based state feedback where the time between sampling points is not known *a priori*, but has known statistical properties. In particular, we assume that the distance between sampling points is an independent sequence of random variables with known mean and variance. (Received August 27, 2013)

1096-93-312 **Duy Nguyen*** (d.nguyen@mcla.edu). *Optimal asset trading under regime switching models.*

This talk focuses on identifying buy and sells prices in both theoretical and computational aspects. Our studies incorporate both buying and selling actions. Asset prices are modeled by a geometric Brownian model, a mean-reversion model or a combination of these two models. The studies establish the existence of the buy and sell threshold levels in such switchable markets. As a result, a sequence of optimal buying and selling times could be constructed using these thresholds. Maximal return can be obtained if trades are done accordingly. Numerical examples are reported to demonstrate the results. (Received August 27, 2013)

1096-93-948 **G S Ladde*** (gladde@usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, CMC 342, Tampa, FL 33620-5700. *Hybrid dynamic inequalities and applications: Hereditary process.* Preliminary report.

In this work, a mathematical model for hereditary interconnected dynamic phenomenon evolving under different measure chains with state dependent discrete events is formulated. By introducing an arbitrary pair of functionals of a pair of flows (measured dynamic flows), a system of systems of hereditary dynamic inequalities with corresponding comparison hybrid dynamic system is outlined. An arbitrary pair of functionals of dynamic flows evolving in two different time scales satisfying a system of systems of hereditary hybrid dynamic inequalities is estimated by the corresponding comparison system of systems of impulsive hereditary hybrid dynamic equations. Moreover, by employing vector Lyapunov/energy functions as functionals of hybrid dynamic flows, several variational comparison results are developed to estimate solution processes of nonlinear nonstationary hereditary hybrid dynamic system in systematic and coherent manner. The obtained results extend and generalize the existing results in a systematic and unified way (Received September 11, 2013)

94 ► Information and communication, circuits

1096-94-45 **Julio Enrique Posada*** (josue635@yahoo.com), Res. nunuapa #19, san salvador, El Salvador, none san salvador, san salvad, El Salvador. *Encryption Through Intrinsic Series.* Preliminary report.

This is a mathematical method developed to encrypt messages. To do this, the author conceived an algorithm to develop a series group called "Intrinsic Series", which are usually found within each and every one of the real numbers. First you build a Coding Matrix consists of 27 rows, one for each letter of the alphabet, and as many columns as we have previously chosen. This algorithm can move freely from one column to another and uses correction factors to move vertically in a single column. The encoding matrix is constructed using the following components: 1 - An Original Number discretion or randomly chosen. This number is located in the position M1.1 2 - A key (formula) to define M2.2 3 - The keys (formulas) to define the numbers in positions M3.3, M4.4, ... With these data the matrix automatically develops and proceeds to encrypt using one or more of the four basic operations: addition, subtraction, multiplication and division. Although the correction factors are always used, transmission can be performed with or without them. After transmission of the message, it is possible and it is suggested that a second (and third or more) encritacion, to give more security to it. (Received June 13, 2013)

1096-94-926 **Kathryn A Haymaker*** (s-khaymak1@math.unl.edu), 203 Avery Hall, Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588. *Structured LDPC codes for flash memory.*

The physical layout of flash memory imposes specific design constraints that affect how existing error-correcting codes are implemented in the memory. One such factor is that approximately half of stored bits have error probability b_1, while the remaining half have error probability b_2, with $b_1 < b_2$. A low-density parity-check (LDPC) code is the nullspace of a sparse matrix, and has a sparse bipartite graph representation that is amenable to efficient iterative message-passing decoding algorithms. In this work, we consider how to arrange codeword bits in the two sections of the memory so that the decoding probability of error goes to zero as the iteration number increases. Our analysis for binary codes leads to a design scheme for nonbinary codes that takes advantage of the differing bit-error probabilities. (Received September 11, 2013)

1096-94-1311 **Akram Aldroubi*** (akram.aldroubi@vanderbilt.edu). *Perfect reconstruction of signals from series of under sampled states.*

Let f an initial state of a dynamical process controlled by an operator A that produces the states $Af, A^2f, \ldots$ at times $t = 1, 2, \ldots$. Let M be a measurement operator applied to the series $Af, A^2f, \ldots$ at times $t = 1, 2, \ldots$. The problem is to recover f from the measurements $Y = \{Mf, MAf, MA^2f, \ldots, MA^Lf\}$. This is the so called Dynamical Sampling Problem. A prototypical example is when $f \in \ell^2(\mathbb{Z})$, X a proper subset of $\mathbb{Z}$ and $Y = \{f(X), Af(X), A^2f(X), \ldots, A^Lf(X)\}$. The problem is to find conditions on A, X, L, that are sufficient for the recovery of f. We will discuss the problem, its applications, and some of the recent results obtained in collaboration with Roza Aceska, Carlos Cabrelli, Jacqueline Davis, Ilya Krishtal, Ursula Molter, Armenak Petrosyan, and Sui Tang. (Received September 14, 2013)

1096-94-2769 **David L. Donoho*** (donoho@stat.stanford.edu). *Optimal Shrinkage of Singular values and Eigenvalues*

We consider recovery of low-rank matrices from noisy data using shrinkage of the data singular values. In an asymptotic framework, where the matrix size is large compared to the signal matrix rank, we show that for each of several popular loss functions, there corresponds a unique asymptotically admissible singular value shrinkage rule, which is a simple scalar nonlinearity. This generalizes results of Shabalin and Nobel (2010). Analogously, we consider estimation of the underlying near-white population covariance from sample covariance using shrinkage of the sample principal components. We assume that the population covariance matrix follows the popular Spiked Covariance Model (Johnstone 2001) and show that for many matrix loss functions used to evaluate performance of covariance estimation, there corresponds a unique asymptotically admissible eigenvalue shrinkage rule, which is a simple scalar nonlinearity, applied individually to each eigenvalue. Joint Work with David Donoho and Iain Johnstone. (Received October 02, 2013)

1096-94-2770 **Ronald R. Coifman*** (coifman@math.yale.edu). *Empirical intrinsic geometry as a tool for invariant parameter extraction.*

We show that we can recover both a Riemannian manifold and corresponding Langevin Dynamics from temporal observations of nonlinear transformations of stochastic Langevin trajectories. We apply this methodology to solve inverse acoustic problems as well to extract slow parameters in complex chemical reactions. (Received October 02, 2013)

97 ► Mathematics education

1096-97-94 **Roni M Ellington*** (roni.ellington@morgan.edu), 5112 Plymouth Road, Baltimore, MD 21214. *Understanding the Experiences African American Mathematics Scholars: A Success Based Framework to Promote and Cultivates Success and Persistence in Mathematics.*

This presentation will include a discussion of pivotal research on high achieving African American mathematics majors that examined the social and cultural factors that support African American mathematics majors' success and persistence in mathematics. Based on this research, a comprehensive success framework was developed and will be explored in this talk. This framework that is being used to encourage African American students to achieve and persist in mathematics and to provide students with the necessary educational, social and cultural and personal support needed to foster their success in the discipline.. Further, there will be a discussion of how the finding of this research and the success framework reflects the stories of highly successful African American mathematicians and a critical analysis of the salient themes that reflect the experiences of African American mathematicians throughout the Diaspora. The talk will end with recommendations as to how the mathematics community can implement this success framework in order to cultivate a diverse cadre of mathematicians and scholars. (Received July 25, 2013)

1096-97-203 **Erin Militzer*** (emilitze@bloomu.edu) and **Rohit Thomas** (rthomas@math.arizona.edu). *Using and Contributing to the Illustrative Mathematics Project: Projects for Your Pre-service and In-service Teachers.*

The Illustrative Mathematics Project is a discerning community of educators dedicated to the coherent learning of mathematics. One of the goals of this site is to be the premier source of freely available online mathematics content for teachers, teacher leaders, assessment developers, curriculum writers, and teacher educators. In light of the Common Core, such a source is a necessary and valuable resource for those using the Common Core State Standards. Educators from all areas are encouraged to not just use the problems and activities posted, but to create and share their own! Over the last year, we guided in-service (graduate level) and pre-service teachers teachers through creating and presenting unique problems at the elementary, middle, and high school levels, to submit to the Illustrative Mathematics Project. In this presentation, we will share our experience with this process, including the problems the teachers in our classes composed, and our advice for future teacher educators who wish to incorporate such projects into their content courses for primary and secondary teachers. (Received August 16, 2013)

1096-97-212 **S. Louise Gould*** (goulds@ccsu.edu), Department of Mathematical Sciences, Central Connecticut State University, 1615 Stanley Street, New Britain, CT 06050-4010. *Geometry and Sewing with Embroidery.*

In 1966 the NCTM published a 43-page volume by Magnus J. Wenninger, Polyhedron Models for the Classroom. This was the original inspiration for many a polyhedron model crafted in cloth. More recently The Symmetries of Things by John Conway et al, has inspired a renewed interest in exploring polyhedral models, including triply periodic polyhedra. This session will focus on pop-up models of the cuboctahedron, two examples of triply periodic polyhedra and include an introduction to the tools and methods. (Received August 19, 2013)

1096-97-228 **Joanne C Caniglia*** (jcanigl1@kent.edu), Teaching, Learning, and Curriculum Studies, Kent State University, Room 404 U. White Hall, Kent, OH 44242. *Supporting Preservice Special Education Teachers with the Academic Rigor of the Common Core:.*

Research in mathematics education is clear that teacher's content knowledge plays an important part in student achievement. However, the special education population continues to be taught by teachers who do not have the content area background they teach nor the belief that they can teach mathematics. The purpose of this presentation will be to show evidence from a study of the effects of mathematical background, self-efficacy, content knowledge, and embedded field experiences. Measures included the state standardized assessments, Mathematics Self-Efficacy Scale – Revised (MSES-R) and the Mathematics Teaching Efficacy Beliefs Instrument (MTEBI). Results show a disconnect between teachers' beliefs that they can teach mathematics to students with disabilities and their content knowledge of K-12 mathematics. Yet, embedding a field experience and teaching collaboratively with special education professors within the mathematics methods course diminishes this disconnect and future teachers begin to realize the importance of mathematical knowledge for teaching. (Received August 21, 2013)

1096-97-238 **Mulugeta Markos*** (mmarkos@ncwc.edu) and **Bishal Karanjit** (bk191945@my.ncwc.edu). *Teaching in College without Calculator.*

There is no clear rule for teachers when to let their students use calculator in the lower level mathematics courses involving basic arithmetic skill. This article analyzes the performances of 198 college students in solving different levels of basic arithmetic skill questions with and without using calculators. Statistical analysis and tests have been conducted to see the correlation and the difference between using and without using calculator. The results of this article indicate that college students do better using calculator when the calculation involves a single operation. Even though most of the students struggle to solve the problems with and without using calculator when the questions involve more than one operation, indices, surd, comparisons, percentages, and approximations, students do better when they are allowed to use calculator. The data in this article provides important information for teachers teaching mathematics and other courses involving basic arithmetic skills, and encourages global study on how and when to use calculator in lower level college classes involving basic arithmetic skill. (Received August 22, 2013)

1096-97-294 **Padmanabhan Seshaiyer*** (pseshaiy@gmu.edu), 4400 University Drive, MS 3F2, Mathematical Sciences, George Mason University, Fairfax, VA 22030, and **Jennifer Suh**. *Inquiry-based problem solving strategies through interactive approaches for engaging students in mathematics.* Preliminary report.

In this session, we will share how students can be engaged and challenged in inquiry-based learning through interactive approaches with mathematics, scientific investigation and critical analysis. Such opportunities with rich mathematical tasks require students to use higher-level critical thinking strategies and self monitoring problem solving skills when engaged in real-world problems that require complex reasoning, communication and a hands-on approach. In this session, we will engage the participants in open-ended exploration with mathematical problem solving and introduce them to some novel interactive problem-solving approaches and opportunities that will benefit students. (Received August 27, 2013)

1096-97-297 **Mikael Vejdemo-Johansson*** (mikael@johanssons.org). *The Junior Mathematical Congress series.*

The Junior Mathematical Congress is a biennial series of week-long youth mathematics events in Europe that has been running since 1992. The JMC meetings gather between 40 and 300 students ages 15-18 for a meeting modeled after the large professional mathematics meetings – the ICM, the EMC, and to some extent the JMM – but inviting students who have gone through a process of discovery without requiring research grade originality to present their projects.

This meeting series distinguishes itself on the European scene as being one of very few youth mathematics events that is peer-based: students talking directly to students, rather than top-down with teachers, researchers and other adults talking to the participating students.

I will be describing the congress series, and my experiences – as a two time participant and two time organizer – with both the effort to organize one of these events, and the effect we have perceived on participants in their interest and dedication to mathematics. (Received August 27, 2013)

1096-97-323 **Nitsa B. Movshovitz-Hadar*** (nitsa@technion.ac.il), Technion - Israel Institute of Technology, Haifa, 32000. *Communicating snapshots of news from contemporary mathematics - an on-going study carried out in senior high-schools in Israel.* Preliminary report.

How might it be possible to communicate the true nature of mathematics to high-school students, giving them a taste of contemporary mathematics without harming the progress in the mandatory curriculum, and despite the fact that they have not accumulated sufficient background to go in-depth into the details of the various pieces of news? To address these challenges we prepared (and are still preparing more) 15-20 minute Math News Snapshots (abr. MNS) as PowerPoint presentations, each evolving around a single piece of news published in the past 30 years in the professional literature. These MNSs are presented by the math teachers to their classes "squeezing" them once a fortnight into the already quite loaded curriculum. We use the metaphor: a bottom-glass boat tour over the stormy ocean of mathematics, as students are exposed to the beauty, the richness, the struggle, the creativity, and the contribution of mathematics to our modern era, without getting wet. The idea was presented at ESU5 in 2007 followed by an action research in one school (Amit Ph.D. study, 2011). In 2012, the Israel Science foundation granted a 3-years study to explore the feasibility of adapting it in the school-system. A sample MNS and some interesting results will be shared with the audience. (Received August 28, 2013)

1096-97-373 **David Patrick*** (patrick@aops.com). *Ten Years Of Working Online With High-Performing Students.*

Since its founding in 2003, the Art of Problem Solving (AoPS) website has been dedicated to providing challenging curriculum and enrichment materials to high-performing students in grades 3-12. AoPS has over 130,000 members overall, and had over 7,000 online school enrollments in the 2012-13 school year. We discuss some of the aspects of the AoPS approach to online learning that have been most effective for mathematically-talented students. (Received August 30, 2013)

1096-97-500 **Paulette N Willis*** (paulette.n.willis@gmail.com), 2000 Bering Dr., Suite 300, Houston, TX 77057. *Outreach without income: An approach to outreach without funding.* Preliminary report.

At the University of Houston we designed a program for high school students that we hope will be replicated by others. Our program does not require grant support, only a few faculty and students (both grad and undergrad) who are dedicated to the students. I will share our grass roots approach to education as well as our successes and failures with you. (Received September 05, 2013)

1096-97-523 **Jane Butterfield***, butter@umn.edu, and **David Clark**. *The kids don't bite, but they never stop asking questions: Two new recruits teach at MathPath.*

What is it like to be a first-time instructor at a summer program for very talented middle schoolers? We found out this past summer, when we were recruited to teach at MathPath for the first time.

Teaching young but mathematically talented students can be intimidating: Their level of in-class involvement is astounding, their questions are thought-provoking, and their attention spans are short. What should new faculty expect when teaching at an advanced summer program for younger students? How can program organizers ensure that new recruits are prepared? We will address these questions from the point of view of new recruits.

Teaching these students is also a wonderful experience. We will describe the outcomes of our classes, and give advice to recruiters and the recruited: What makes a good candidate? What benefits do new faculty get from participating in such a program? And after our first experience, would we do it again? (Received September 05, 2013)

1096-97-527 **Elizabeth A. Burroughs*** (burroughs@math.montana.edu), Department of Mathematical Sciences, Montana State University, Bozeman, MT 59717-2400. *Three Specialized Courses for Preparing Secondary Mathematics Teachers.*

The major in mathematics with a teaching option at Montana State University includes, among other mathematics and education coursework, three specialized courses focusing on mathematics for teaching. The courses are titled *Higher Mathematics for Secondary Teachers*, *Modern Geometry*, and *Mathematical Modeling for Teachers*. Though the courses have been an essential part of our mathematics teaching program at MSU for nearly two decades, the *Mathematical Education of Teachers II* report has provided our faculty members the opportunity to reexamine the content and articulation of these courses. I will discuss some of our successes and challenges in teaching these courses and invite audience members' ideas and reactions. (Received September 05, 2013)

1096-97-577 **Justin D Boyle*** (boylej@unm.edu), NM. *Knowledge and Beliefs for Teaching Proof: A Conceptual Framework for Mathematics Teacher Educators.*

Mathematics teachers require a broad range of knowledge and beliefs to support their students understanding of reasoning and proving. Several standards for mathematical practice include reasoning and proving such as developing viable arguments and critiquing the reasoning of others. A reasoning and proving conceptual framework was developed for mathematics teacher educators as a guide to design learning activities for teacher development and include the following four dimensions: criterion of proof, purpose, equity and opportunity. These four dimensions combined are mapped onto knowledge (mathematical and pedagogical) and beliefs (mathematical and student), and aim to provide a complete conception of proof for teaching. An example of a mathematical task is used to ground the theoretical need of each framework dimension. Furthermore, two narrative cases of pre-service teachers are shared to further justify the need for the development of all four dimensions. In conclusion, if teachers are limited in any of the four dimensions, then students will continue to develop limited or distorted understandings of mathematical proof. (Received September 06, 2013)

1096-97-664 **Kien H Lim*** (kienlim@utep.edu), Department of Mathematical Sciences, University of Texas at El Paso, 500 W. University Ave, El Paso, TX 79968-0514, and **Eric Freudenthal** (efreudenthal@utep.edu), Department of Computer Science, University of Texas at El Paso, 500 W. University Ave, El Paso, TX 79968-0518. *iMPaCT-Math: Using Programming Activities to Motivate Exploration of Foundational Concepts in High-School Algebra.*

iMPaCT-Math is a project where a team of university researchers and math teachers are developing a set of learning modules for use in a high-school algebra classrooms. These modules provide an experiential-visual context for students to make connections across multiple representations: (a) statements in a program, (b) computational process; (c) graphical output, and (d) underlying mathematical concepts such as slope and Cartesian coordinates. The activities are designed to foster mathematical thinking and conceptual depth. Most activities utilize summation within simple programs that can be executed on graphing calculators like TI-83. These programs, and their corresponding graphical outputs, enable students to discover their own math and logic errors in a manner that encourages further investigation or reflection. In this presentation, we will illustrate how writing/modifying simple programs involving "while" loops and anticipating the graphical outputs can reinforce students' understanding of slope and why a constant second difference will cause the graph to curve. Information about our project is available at http://www.impactstem.org. (Received September 08, 2013)

1096-97-693 **Ellina Grigorieva*** (egrigorieva@twu.edu), PO BOX 425262, Denton, TX 76204. *Problems and methods that develop creativity.*

It is known that students have a hard time when trying to solve math problems involving integers, perhaps due to the fact that they study numbers in elementary school and basically never touch the topic again throughout the entire math curriculum. Many don't find arithmetic problems interesting or of much use in our everyday life, but nevertheless it is important because solving problems empowers us. This talk will be focused on methods of solving challenging math problems. It will demonstrate connection between different fields of mathematics and how presented collection of the problems can develop creative thinking and ability to conduct own proof. Additionally, this presentation and handouts can be helpful for math teachers and college professors who would like to use it as an extra resource in their classroom. (Received September 09, 2013)

1096-97-830 **Sarah E. Anderson*** (sarah5@g.clemson.edu) and **Gretchen L. Matthews**. *Crafting activities which analyze QR codes.*

Emergent technology is constantly changing the landscape of the modern classroom, where students are exposed to new technology and communication methods at an early age. For example, elementary students are using QR codes to access homework and answer keys. But how much of the mathematics behind these communication methods do students comprehend?

In this talk, we will give examples of how to implement engaging coding theory and cryptography activities to explain QR codes as well as how to introduce related technology. In addition, we will share our experiences using these activities, including what we learned, mistakes we made, and student feedback. (Received September 10, 2013)

1096-97-831 **David Auckly*** (dav@math.ksu.edu), Kansas State University, Mathematics Department, Manhattan, KS 66502, and **Tatiana Shubin** and **Henry Fowler**. *Math Circle Examples from Kansas and the Navajo Nation.*

The math circle model is becoming a well known model for outreach programs, and there are many resources for people interested in running math circles including the National Association of Math Circles, the MAA SIGMAA on Math Circles for Students and Teachers, and the Math Teachers Circle Network. This presentation will describe math circles in the Navajo Nation as well as at Kansas State University, and point out resources for people interested in forming their own math circle. (Received September 10, 2013)

1096-97-982 **Tatiana Shubin*** (tatiana.shubin@sjsu.edu), Department of Mathematics and Statistics, San Jose State University, San Jose, CA 95192-0103, and **Henry Fowler** and **David Auckly**. *Navajo Nation Math Circles Project (NNMCP).*

The NNMCP includes three major components: math circles at a number of middle and high schools on the Navajo Nation, teacher workshops, and a two-week summer camp. This program has developed a new model of math circles suitable for the underserved community with geographically challenging situation. Teacher workshops serve as a mechanism to sustain these circles by helping teachers to understand this method of mathematical interaction; participating teachers also develop inquiry-based style of teaching in their classrooms. The workshops take place during school year and in the summer, and they include Math Circle and Common Core State Standards parts. The two-week summer camp combines strong mathematical and cultural components;

the first summer camp was held at Diné College in 2013 and served middle and high school students from across the Navajo Nation. This talk will discuss all three aspects of the program and ways of creating similar programs for other communities. (Received September 11, 2013)

1096-97-986 **Brandy S Wiegers*** (bwiegers@sfsu.edu), SFSU Dept of Math (TH 937), 1600 Holloway Ave, San Francisco, CA 94132. *SFSU (CM)^2: Creating Momentum Through Communicating Mathematics: Graduate students mentoring K-12 students in-school, after-school, and over the summer.*

The (CM)^2: Creating Momentum Through Communicating Mathematics program at San Francisco State is a NSF-GK12 program for Masters' level mathematics students. The (CM)^2 graduate student fellows receive their NSF fellowship in exchange for committing to 1-year mentoring and supporting Bay Area K-12 classrooms. Beyond the fellows' work in local middle and high schools the (CM)^2 fellows are also the primary instructors for the San Francisco Math Circle, a weekly after-school program that engages 2nd-12th grade students and their teachers in mathematical problem solving that moves beyond the curriculum. San Francisco Math Circle exposes students to advanced mathematical topics including mathematical tilings & knots, geometry, mathmagic, and so much more! Last year (CM)^2 expanded to include a summer math program: (MC)^2, Math Circle Math Camp. The (MC)^2 Math Camp was completely imagined, planned, and run by SFSU graduate students for Bay Area high school students, many of whom had never been outside of San Francisco. This program was just one more success to celebrate as the (CM)^2 program concludes the last year of NSF funding. This talk is our chance to share lesson learned, share successes, and an opportunity to share post-grant plans. (Received September 12, 2013)

1096-97-1070 **Brian J. Birgen*** (brian.birgen@wartburg.edu), 100 Wartburg Blvd., Waverly, IA 50677, and **Mariah H. Birgen** (mariah.birgen@wartburg.edu), 100 Wartburg Blvd., Waverly, IA 50677. *Modeling Calculus: A first course in the Calculus Sequence.*

In the first Calculus course at Wartburg College, students start with Euler's Method learning how to compute numerical solutions of differential equations. Examples include drug metabolism, parachute air resistance, predator-prey systems, and bungee cords. As a final project, students find journal articles from partner disciplines and replicate the models with the numerical solution software. The course develops geometric intuition and the language of differential equations and is a fundamental part of the Calculus sequence we offer to all science, Engineering and math students. We will discuss practical considerations for delivering this class as well as the advantages for the students. (Received September 12, 2013)

1096-97-1123 **Peter R Turner*** (pturner@clarkson.edu), School of Arts & Sciences, Clarkson University, 8 Clarkson Avenue, Potsdam, NY 13699-5800. *Modeling across the Curriculum.*

This talk will introduce the session by discussing a number of recent activities. The first SIAM-NSF workshop on Modeling across the Curriculum was held in August 2012 and the final report has recently been published. It is available at www.siam.org/reports/modeling_12.pdf Funding for a follow up workshop to develop the ideas further has recently been awarded and plans for that meeting will also be discussed. The INGenIOuS workshop, run jointly by AMS, ASA, MAA and SIAM, will also be included in the discussion. (Received September 13, 2013)

1096-97-1145 **Laura McLeman*** (lauramcl@umflint.edu), Mathematics Department, 303 E. Kearsley St., Flint, MI 48502. *A Capstone Experience for Teacher Candidates.*

Future secondary mathematics teachers need a focused capstone experience in their preparation that provides them opportunities to examine the mathematics they will teach from an advanced perspective (CBMS, 2001). To implement these recommendations, our department used the Common Core State Standards in Mathematics as a guide in developing the structure of a new capstone course for our teacher candidates. In this talk, I will offer commentary on the successes and challenges of such a model, as well as future plans. (Received September 13, 2013)

1096-97-1176 **Sam Vandervelde*** (svandervelde@stlawu.edu). *Why MathPath Works.*

MathPath bills itself as an advanced summer camp for students age 11 to 14 who show high promise and love mathematics. Since its inception in 2002 MathPath has more than doubled in size to reach a stable population of 100 students, who tell us that "It's like being part of a giant, fun, smart family for a month. It's the best month I have over the summer." The speaker, who has taught at MathPath since 2006 and who recently became a member of the board, will identify aspects of the program—some obvious and some less apparent—that have contributed to the success of MathPath over the years. (Received September 13, 2013)

1096-97-1306 **Cody L Patterson*** (cpatterson@math.arizona.edu), Department of Mathematics, 617 N Santa Rita Ave, PO Box 210089, Tucson, AZ 85721. *Developing preservice teachers' conceptual understanding of algebra.* Preliminary report.

The Common Core State Standards for Mathematics call for increased rigor not only in students' ability to solve algebra problems, but also in their understanding of the methods they use to solve them. In order to help students meet the new standards, teachers must come to view the methods of algebra as problem solving strategies that are supported by properties of number systems, rather than as procedures to be executed by rote. In this presentation, we discuss some abstract algebra and number theory tasks designed to shed light on procedures commonly used in secondary mathematics. We will also present results of a pre-course and post-course survey that provided evidence of preservice teachers' enhanced understanding of these procedures. (Received September 14, 2013)

1096-97-1369 **Kenneth R Berg*** (krb@math.umd.edu), University of Maryland, College Park, Dept. of Mathematics, College Park, MD 21742. *From the Spiral Program at UMCP: Research projects suitable for students after completing a first course in mathematical proofs.*

Spiral at UMCP ran from 2003 through 2013. Students from Historically Black Colleges and Universities came for an intense six week program designed both to teach mathematical subject matter and provide experience in open-ended exploration of substantial mathematical questions. Typically students had completed two years of a mathematics major and had had some but not extensive exposure to the writing of mathematical proofs. Topics suitable for this level were chosen in collaboration with the students. Students explored and discussed their topics but an essential goal was that, by the end of the program, they could have results that could be precisely stated and carefully proved.

Students were guided in their explorations, but to a large extent they were left on their own to accomplish whatever they could accomplish. Results were often new in the sense that neither the students nor the mentors knew them at the outset.

I will describe some of the projects, the mathematical results, and the impact on the students. (Received September 15, 2013)

1096-97-1427 **Chepina Rumsey*** (chepina@ksu.edu). *Collaboratively Planning and Teaching an Inquiry Lesson Aligned with CCSS in an Elementary Mathematics Methods Course.*

There are many components that need to be integrated into an elementary mathematics methods course, and one aspect is developing the pre-service teacher's (PST) skills in planning inquiry lessons emphasizing both the content and practice standards within the CCSS. The question of negotiating what to include in a methods course and for how many days can be difficult given the number of important topics. This project, conducted with two semesters of elementary mathematics methods classes, was an attempt to integrate several meaningful components in a methods course while modeling both lesson planning and teaching strategies with a focus on the CCSS.

The purpose of this presentation is to highlight the data supporting the benefits of this classroom endeavor. In this presentation, the participants will learn about a project in which PSTs were engaged in (1) learning about teaching with an emphasis on the CCSS, (2) creating a lesson integrating Common Core standards (CCSS) collaboratively with a professor and classroom teachers, (3) observing the lesson taught to actual elementary school students, and then (4) reflecting on the entire process. (Received September 15, 2013)

1096-97-1483 **Eric Hsu*** (erichsu@sfsu.edu), 1600 Holloway Avenue, Science 211, San Francisco, CA 94132. *Evolving Content and Technology in a Capstone Course for Future Secondary Math Teachers.*

The presenter has taught six iterations of a capstone course for future secondary math teachers and this spring begins a seventh. The content, course framing and use of technology has evolved over time in response to student needs and iterative improvement. The presenter will present new web-based courseware, guiding principles and their implications for course design in response to the introduction of the Common Core standards. (Received September 15, 2013)

1096-97-1491 **Jennifer M Lewis*** (jmlewis@wayne.edu), 223 College of Education, 5425 Gullen Mall, Detroit, MI 48202. *Using the Standards for Mathematical Practice to Assess the Performance of Preservice Teachers.*

This session shows the use of the Standards for Mathematical Practice (SMPs) from the Common Core State Standards (2010) as a framework for structuring and assessing the performance of early preservice teachers in an elementary mathematics methods course. The SMPs were used at the end of the course as a rubric to assess student performance. The preservice teachers had to demonstrate understanding of each of the SMPs, with evidence of their efforts to help children work on each SMP in a multimedia final project. The SMPs are used as reference points in this course for preparing, enacting and appraising instructional activities with children, for viewing videotapes of other teachers' mathematics instruction, for studying elementary mathematics curricula, and for interpreting children's work—and ultimately as the rubric for students' performance in the course. The focus of this session will be the analysis of students' final projects. Preliminary analyses suggest that preservice teachers demonstrate higher proficiency in enacting the SMPs regarding problem-solving and sense-making, and the construction and critique of mathematical arguments. In contrast, they struggle with mathematical modeling, the use of appropriate tools, and the use of structure. (Received September 15, 2013)

1096-97-1631 **Mika K Seppala*** (mika.seppala@myweps.com). *Student Profiling and Mathematical Models for MOOCs.*

Massive Open Online Courses collect lots of student log data. This can be used to support students in an way not seen before. Mining the log data, the WEPS online service (myweps.com) develops study path suggestions to help students to succeed.This is especially effective in online courses, whose resources are rich enough to support multiple learning styles.

The myweps.com educational log data mining is based on modeling MOOCs as Riemann surfaces. This mathematical view on MOOCs, combined with student profiling, allows us to mine the log data in an effective way. The study path suggestions are not based on personal views of instructors, but rather on the objective data of the successes and failures of students, and on the detailed understanding of their learning styles. (Received September 16, 2013)

1096-97-1695 **Yvonne Lai*** (yvonnexlai@unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588. *Clear instruction of mathematical practice: Preparing teachers to use rich and ordinary problems to teach Common Core standards for mathematical practice.*

Preservice education aims to improve teachers' ability to teach mathematical practice through particular content. Teaching mathematical practice requires experience with and an explicit understanding of the various aspects of doing mathematics - such as those laid out by the Common Core standards for mathematical practice. We as mathematics faculty who teach preservice teachers must be able to

- identify key mathematical practices that can arise when solving rich and ordinary problems
- guide teachers to identify key practices
- collaborate with pedagogy/methods instructors so that teachers understand how and have the confidence to harness knowledge, gained in teacher education, when teaching future students.

Rich problems include those that readily give way to many alternative solutions within the grasp of students. Ordinary problems include those often called "routine" – yet, as we will argue here, even these problems can be used to motivate mathematical reasoning and therefore learning. In this presentation, we demonstrate, through a small collection of rich and ordinary problems of middle and secondary mathematics, how practices can be taught as a means to mathematical reasoning, in a way that connects content and pedagogy. (Received September 16, 2013)

1096-97-1732 **Sandra Richardson*** (srichardson@vsu.edu). *Using Technology Tools to Communicate Mathematics.*

This session will introduce successful means of incorporating iPad applications and other web-based technology tools to effectively communicate mathematical concepts, representations, and approaches in undergraduate mathematics courses, with special emphasis on courses for pre-service secondary mathematics teachers. Technology tools and ideas for communicating mathematics through polling, assessments, activity simulations, and tactile learning tasks will be shared. (Received September 16, 2013)

1096-97-1748 **Priscilla S. Bremser*** (bremser@middlebury.edu), Department of Mathematics, 14 Old Chapel Road, Middlebury, VT 05753. *The Challenges of Preparing Future Elementary Teachers at a Small Liberal Arts College.* Preliminary report.

While many small colleges offer elementary teaching licensure programs, course requirements vary. What is a mathematician to do when those requirements include no mathematics courses? I will describe an elective course I've developed within the constraints at my institution, and lay out the challenges and open questions that remain. (Received September 16, 2013)

1096-97-1791 **Anna Weltman*** (weltman.anna@gmail.com), Saint Ann's School, 129 Pierrepont St., Brooklyn, NY 11201. *MArTH Madness: Building a Culture of Creating Math Through Art at Saint Ann's School.*

What opportunities do students have to make math? Given that many mathematicians agree that what motivates them is the drive to create mathematics they experience as beautiful, this is an important question for math educators. At Saint Ann's School, in Brooklyn, NY, our experience has been that creative math can have its greatest effect in the earlier stages of math education. Choice-making, experimentation, and imagination - all of which are part and parcel of working like a mathematician - should have a large role in school math.

I began the mathematical art program in 2011 to better incorporate these ways of interacting with math into our curriculum. The program has grown to include electives for middle and high school students, an annual, school-wide festival, and informal making of math art in classrooms, hallways, and lunchrooms all over the school, for students in third through twelfth grades. The blog Math Munch also provides students with ways to interact with math art outside of school. Through this program, we have watched students begin to see themselves as mathematicians in ways that go beyond the usual habits and practices of a math classroom. We hope our program can serve as an example of a way to build mathematical community and encourage engagement with math. (Received September 16, 2013)

1096-97-1848 **Brigitte Lahme*** (lahme@sonoma.edu) and **Ben Ford**. *Applying Lessons from Professional Development Work to Pre-service Content Courses.* Preliminary report.

Since 2010, we have worked with hundreds of teachers in long-term professional learning communities to transition to the Common Core State Standards. This has led to significant redesign of our pre-service math content courses for elementary teachers, as we come to understand the biggest challenges faced by classroom teachers in implementing the CCSS and learn about the huge variety of resources available in the professional development world. We specifically mention approaches to fractions, modeling, and mathematical practices. (Received September 16, 2013)

1096-97-1928 **Heidi Burgiel*** (hburgiel@bridgew.edu), Mathematics Department, Bridgewater State University, Bridgewater, MA 02325. *Shapes (and Rates) of Vases.*

This activity found in middle- and high-school classrooms promotes deep understanding of rates of change, including second derivatives.

Pour 10cc of water into a vase, then measure the height of the water. Repeat this process until the vase is full, then graph height vs. volume. How is the shape of the graph related to the shape of the vase?

In discussing the results of this activity, students who have never taken calculus offer observations about rates of change and increasing and decreasing slopes; in this context the second derivative is accessible and tangible. (Received September 16, 2013)

1096-97-1987 **Glenn Stevens*** (ghs@math.bu.edu). *Exploration with PROMYS.*

The Program in Mathematics for Young Scientists (PROMYS) has offered a six week immersion experience in mathematics to approximately 80 high school students each summer since 1989. Distinctive of the PROMYS approach is its focus on Mathematical Habits of Mind. The presentation will illustrate these principles through an examination of several important features of the PROMYS student experience, including: (1) Immersion in significant mathematical activity; (2) Depth over breadth; (3) Experience before formality; (4) The art of questioning answers; (5) Sustained effort and persistence; and (6) Collaboration within a supportive multi-tiered mathematical community. Concrete examples of particular mathematical activities will be described. As time permits, we will also discuss logistical issues, including recruitment and selection of participants. (Received September 17, 2013)

1096-97-1999 **Davida Fischman*** (fischman@csusb.edu), Dept. of Mathematics, California State University, San Bernardino, 5500 University Pkwy., San Bernardino, CA 92407, and **Madeleine Jetter** (mjetter@csusb.edu), Dept. of Mathematics, California State University, San Bernardino, 5500 University Pkwy., San Bernardino, CA 92407. *Developing Mathematical Habits of Mind in Preservice Teachers.*

Mathematicians and mathematics educators believe that mathematics should make sense, and should help make sense of the world. However, all too frequently standard math course materials do not support sense-making and other habits of mind for teaching mathematics. To address this issue, at CSUSB we have been working to increase alignment with the Standards for Mathematical Practice (SMPs).

This work has been strongly influenced by long-term partnerships between CSUSB mathematicians, mathematics educators, and local school district leaders. With the support of CSUSB NSF- and State-funded programs, districts are making significant curricular and instructional changes; we will discuss how we are modifying the CSUSB teacher preparation program based on ongoing conclusions from this work.

In this presentation we will 1. Examine the structures we have put into place to align courses with the aims of the SMPs; 2. Consider the changes in content and assessment of math courses that have followed this alignment; 3. Share specific mathematical tasks that have been productive in college math courses that are aligned to the SMPs; 4. Share some challenges and opportunities in this work. (Received September 17, 2013)

1096-97-2043 **W Gary Martin*** (wgarymartin@auburn.edu), 5040 Haley Center, Auburn, AL 36849, and **W. James Lewis** and **Marilyn E. Strutchens**. *MTE-Partnership: Mathematicians, Mathematics Educators, and Secondary Mathematics Teachers Working Together to Transform the Preparation of Teachers.*

The MTE-Partnership consists of 38 universities and their partners working together to transform secondary mathematics teacher preparation in light of the Common Core and METII. The "networked improvement community" model, which incorporates precepts of improvement science and network design, is being used to address significant issues facing preparation programs, including the mathematical preparation of candidates, creating more productive clinical experiences, and recruiting and retaining more candidates. To effectively address these issues requires significant roles for mathematics, mathematics teacher educators, and K12 personnel working collaboratively. (Received September 17, 2013)

1096-97-2071 **Sybilla Beckmann*** (sybilla@math.uga.edu), Department of Mathematics, Boyd Graduate Studies Building, University of Georgia, Athens, GA 30602, and **Andrew Izsak** (izsak@uga.edu), Dept. of Mathematics and Science Education, Aderhold Hall, University of Georgia, Athens, GA 30602. *How future teachers use two distinct definitions to reason about proportional relationships.* Preliminary report.

The Common Core State Standards for Mathematics ask students to construct viable arguments that use stated assumptions, definitions, and previously established results (Mathematical Practice Standard 3). We have identified two distinct definitions for what it means for two quantities to be in an A to B ratio, which parallel two quantitative definitions for division. In ongoing empirical work we are investigating how future teachers in two programs, a middle grades certification program and a secondary certification program, use the two definitions in constructing arguments. Our preliminary findings include that future teachers in both programs are able to use both definitions, that their use of the two definitions can reveal strengths or weaknesses in their understanding of division in terms of quantities, that they sometimes draw on the definitions to argue (correctly) that a relationship is not proportional, and that applying the definitions in situations that involve the distributive property is especially challenging. (Received September 17, 2013)

1096-97-2072 **Christina C Chestnut*** (christina@stokedonsteam.org), **Anneliese E Haines** (anneliese@stokedonsteam.org) and **L E Nichols** (l@stokedonsteam.org). *The effects of STEAM-centered modules on student learning.* Preliminary report.

In this study we focus on the effects of STEAM-centered (Science, Technology, Engineering, Art, and Mathematics) workshops (modules) on students' learning; more specifically, we look to describe the impact that the addition of Art to a STEM activity has on student understanding and mastery. The modules are developed through a Project-Based Learning lens, consisting of loosely-defined tasks driven by well-defined outcomes. One of the modules we use in the research is the creation of a board game. For each participant we are collecting pre- and post-workshop surveys for each module, conducting one-on-one interviews, and recording researcher observations during the activities. A descriptive analysis will be conducted on these data sources to develop a profile of our case study subjects, a subset of the participants. From here, we plan to develop further studies on this area of research so as to understand empirically the STEAM approach to learning. (Received September 17, 2013)

1096-97-2099 **Ben McCarty*** (ben.mccarty@memphis.edu). *A story of...*

Mathematics and literature aren't generally seen as having much in common. However, like any good epic tale, there are themes woven into the very fabric of a solid mathematics curriculum. We will look at such themes, and how they can influence and guide our instruction. (Received September 17, 2013)

1096-97-2129 **Steven R Dunbar*** (sdunbar@maa.org), 1740 Vine Street, Lincoln, NE 68588. *MAA's American Mathematics Competitions.*

How do you get bright students hooked on mathematics? How do you keep teachers intellectually engaged and pedagogically innovative? A proven way is to involve them both in mathematics competitions with great problems that span the curriculum. The Mathematical Association of America has continuously sponsored nationwide high-school level math contests since 1952. The American Mathematics Competitions is now the oldest, largest, and most prestigious STEM competition in the U.S. The competition sequence now has 5 different contests at increasing levels of mathematical sophistication. Students who succeed at the top level on these contests become the team representing the U.S. at the annual International Mathematical Olympiad (IMO). The Mathematical Olympiad Summer Program which is the training program for the IMO team each summer also teaches over additional 50 students deep understanding and problem-solving skills, and most go on to careers in mathematical sciences. I'll give an overview of the full competition and outreach program. (Received September 17, 2013)

1096-97-2140 **Nadia Monrose Mills*** (nmonros@ncsu.edu). *Students' Understanding of the Limit of a Sequence: A Case Study of Three Pre-service Elementary Teachers.*

With a continually increasing STEM focus in education, elementary teachers must be prepared to teach all STEM subjects including mathematics. To prepare them for teaching mathematics, prospective elementary school teachers at a southeastern university in the US are required to take calculus. Case studies of three pre-service elementary students who participated in task-based interviews to solve limits of sequences problems will be presented. The concept of limits is an important and fundamental concept that forms the foundation for understanding calculus and other rigorous mathematics topics. Student misconceptions not only affect their ability to understand limits but also translate to difficulties for student understanding of infinite processes, the sum of infinite sequences, continuity of a function, the derivative and the integral (Roh, 2008). Results from this study suggest that the students with more conceptual understanding of limits use multiple representations to justify their solutions and the students did not use the formal definition for the limit of a sequence to justify their solution. Some implications for teaching are that students should be exposed to different representations, and the similarities between the limit of a function and the limit of a sequence. (Received September 17, 2013)

1096-97-2149 **Lou DiGioia*** (lou@mathcounts.org), MATHCOUNTS Foundation, 1420 King Street, Alexandria, VA 22314. *MATHCOUNTS - 3 unique approaches to extracurricular math.*

For 31 years, MATHCOUNTS has engaged students in fun and challenging middle school math programs. The best-known is the MATHCOUNTS Competition Series, which provides talented students the opportunity to challenge themselves and test their skills against their peers. With over 550 events held every year, the MATHCOUNTS Competition Series is the only middle school math contest with in-person interschool competitions in every U.S. state and territory.

Recently, MATHCOUNTS launched two new programs to provide additional ways to engage students. The National Math Club provides the free resources and structure to any school or group that wants to hold an organized math club. In addition to materials and activity plans for the meetings, clubs can earn prizes for their participation. The National Math Club provides participants with an opportunity to engage in math without any competitive element.

The Math Video Challenge lets students engage in math through the use of video technology. Teams create videos that teach a MATHCOUNTS problem and show the real world application of the math concept used in the problem. Top videos advance and win prizes.

Session participants will learn how to engage middle school students in each of the 3 MATHCOUNTS programs. (Received September 17, 2013)

1096-97-2377 **Glenn Ledder*** (gledder@unl.edu). *Using a Virtual Laboratory to Teach Mathematical Modeling.*

Mathematical modeling involves the construction, analysis, and validation of mathematical systems based on assumptions that are believed to fit a physical system of interest. Constructing a model requires physical insight best gained by observation or experiment. While a mathematics classroom is not an ideal setting for observation and experiment in the real world, it is just the right place for observation in a virtual world. In this talk, we show how to use the BUGBOX-Population virtual laboratory to teach mathematical modeling. The laboratory provides the data and observations needed to develop stage-structured models for the population growth of an insect species, with four varieties allowing for a transition from very simple to almost realistic. We use the model to make predictions about population growth and then validate the model by testing the predictions. (Received September 17, 2013)

1096-97-2431 **Ayşe A. Şahin*** (asahin@depaul.edu). *Using the ideas of Calculus to transition teachers from a computational to a conceptual understanding of functions.* Preliminary report.

Programs for middle school mathematics teachers typically include a course in Calculus. We will describe one such course and give examples of how the design of the course helped teachers understand functions as models and the slope of a line as a rate of change. (Received September 17, 2013)

1096-97-2454 **Guershon Harel*** (harel@math.ucsd.edu). *Developing and Sustaining Professional Communities of Teachers around Mathematical Content and Student Intellectual Need.*

In this talk we discuss our effort to create and sustain a community of teachers organized around a shared purpose and coordinated effort to improve student learning. The collective actions carried out by the community are oriented within a conceptual framework, called DNR-based instruction in mathematics. (Received September 17, 2013)

1096-97-2598 **Ruth Rodriguez*** (ruthrdz@itesm.mx), Math Deparment, Office A7227, Av. E. Garza Sada 2501, Col. Tecnologico, 64849 Monterrey, Nuevo Leon, Mexico. *Teaching and Learning Differential Equations for Engineers through Modelling and Technology.* Preliminary report.

The purpose of this paper is to present an experience of an educational practice in a private university in México about a different way to teach a Differential Equations course for future engineers based on a didactical proposal developed through modelling. This proposal emphasizes that Mathematics is a human activity that answers several problems of different nature, and throughout this problem solving activity it is likely that the emergence of mathematical concepts, notions and procedures occurs. We want to justify in this chapter how modelling is an important base to design this proposal. Evidence has shown that future engineers achieve better understanding of the math concepts after living this educational practice and further develop other skills, as social, communicative, modeling and technological, along with the mathematical. (Received September 17, 2013)

1096-97-2659 **Paul E. Seeburger*** (pseeburger@monroecc.edu), Monroe Community College, 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 several 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. 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 17, 2013)

1096-97-2664 **Mira Bernstein*** (mira@mathcamp.org). *"Out of nothing I have created a strange new universe": the role of summer mathematics programs in the educational paths of talented students.*

The quote in the title is from Janos Bolyai, on his discovery of non-Euclidean geometry. It also serves as the motto of Canada/USA Mathcamp, a summer program for mathematically talented high-school students, with which I have been involved since 1997.

Like any residential program, Mathcamp is indeed its own little universe, a world apart. For five weeks every summer, we create a remarkable community, rooted in the thrill of mathematical discovery, the freedom of choosing one's own intellectual pursuits, and the joy of sharing them with others. For many students, taking part in such a community is a transformative experience: a source of intense happiness and mathematical and personal growth. I am sure something similar happens at other summer programs as well.

As organizers of these mini-universes, we have to ask ourselves: how do we want the students' experience at our programs to fit into the broader context of their lives, their ongoing mathematical (and non-mathematical) education, and the larger communities of which they are part? And, consistent with this, how should our programs interact with each other, with other math enrichment venues, and with the larger world of education? These are questions to which I do not have answers, but I do have a few thoughts to share. (Received September 17, 2013)

1096-97-2732 **Daniel Zaharopol*** (danz@artofproblemsolving.org), PO Box 390389, Cambridge, MA 02139. *A viable pathway for underserved students to enter advanced mathematical study.*

There are overwhelming obstacles for underserved students to enter advanced mathematical study. These challenges include background knowledge, cost, community support, and access to and knowledge of opportunities. We will explore these obstacles and how to overcome them through the lens of the Summer Program in Mathematical Problem Solving, a three-week residential program for underserved New York City middle school students with talent in math that has been successful at helping students enter selective high schools as well as summer programs and math circles.

Existing program directors will come away with new strategies successfully bringing underserved students into their programs. Teachers and individuals with an interest in this area will discover opportunities to get involved and will gain some effective tools for their work. (Received September 18, 2013)

1096-97-2736 **Mara Alagic*** (mara.alagic@wichita.edu), Wichita State University, 1845 Fairmount, Wichita, KS 67226-0028. *Mathematical Fidelity of Virtual Manipulatives: Teacher Candidates' Perceptions.*

Virtual manipulatives as cognitive tools, dynamic and interactive, Web-based representations permit users to engage in mathematical meaning making. This research examined teacher candidates' beliefs about and perceptions of the mathematical fidelity of a certain set of freely available virtual manipulatives related to problem solving. Preliminary findings suggest that an assumption that the degree to which the mathematical object is faithful to the underlying mathematical properties of that object in the virtual environment (mathematical/cognitive/pedagogical fidelity) has been granted by teacher candidates to virtual manipulatives designers automatically, without checking. Further qualitative probing was carried through to better understand the nature of such assumptions. (Received September 18, 2013)

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 Lectures

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1096-A0-10 **Michael Starbird***, University of Texas at Austin, Department of Mathematics, Austin, TX. *Effective thinking and mathematics*

A wondrously romantic belief is that brilliant thinkers magically produce brilliant ideas: an apple knocks out Newton and calculus appears in a fevered dream. We can enjoy fanciful fables of leaps of genius, but we should not be fooled into believing that those fables are fact. Brilliant innovators are brilliant because they practice habits of effective thinking that inevitably carry them step by step to works of insight and even genius. No magic and no leaps are involved. Habits of effective thinking and creativity can be taught, learned, and mastered; and mathematics provides a wonderful vehicle to convey these techniques. Anyone who practices them will inevitably create new insights, new ideas, and new solutions in mathematics and life. (Received April 08, 2013)

1096-A0-11 **Jill Pipher***, Department of Mathematics, Brown University, Providence, RI. *The mathematics of lattice-based cryptography.*

Lattice-based cryptography has become a major focus of research in the field of public key cryptography: various schemes offer efficiency, provable security, resistance to quantum computing based attacks, or most recently, fully homomorphic functionality. This chapter in cryptography research took off in 1996-97 with Ajtai's breakthrough paper "Generating Hard Instances of Lattice Problems" and a quick succession of three lattice-based public key encryption schemes: NTRU, GGH, and Ajtai-Dwork. Up to then, lattices had been primarily used in the cryptanalysis of a number of public key potential alternatives to RSA, known as knapsack schemes. This lecture introduces the mathematical ideas in this subject from 1996 to the present, ending with a discussion of fully homomorphic encryption. It will be accessible to a wide audience. (Received April 09, 2013)

1096-A0-12 **William Dunham***, Department of Mathematics, Muhlenberg College, Allentown, PA. *Heron, Newton, Euler, and Barney.*

Heron's formula, giving the area of a triangle in terms of the lengths of its sides, is one of the great, peculiar results of plane geometry. It is thus to be expected that, over the years, there have been multiple demonstrations of this remarkable formula.

Here, I consider four such proofs. Heron's original was a clever if convoluted exercise in Euclidean geometry. Centuries later, Isaac Newton gave a demonstration whose heavy lifting was done by algebra rather than geometry. Leonhard Euler's proof was geometric and exhibited his characteristic flair. Then, in an unsolicited 1990 letter, someone named Barney Oliver shared with me an elegant trigonometric argument where the symmetry of the formula was mirrored by the symmetry of the proof itself. (Received April 09, 2013)

1096-A0-13 **Sarah-Marie Belcastro***, Sarah Lawrence College, Bronxville, NY. *Snark attack! Visualizations of "uncolorable" graphs on surfaces.*

You've probably seen a common (indeed, iconic) drawing of the Petersen graph as a five-pointed star joined to a pentagon; it graces the covers of journals and textbooks. The Petersen graph is Everyone's Favorite Graph™, and is the smallest example of a class of graphs known as *snarks*. Snarks are central to a proposed generalization of the Four Color Theorem to topological surfaces other than the sphere (Grünbaum's Conjecture). For this reason, it is of interest to consider how snarks may be drawn (*embedded*) on these surfaces.

In this talk, we will generalize from the Petersen graph to snarks at large, and give the topological graph theory background needed to appreciate snark embeddings—all the while relating aspects of snark diagrams to the mathematics exhibited therein. Then we will survey what is known about snark embeddings on low-genus surfaces, with examples from recent research and discussion of the mathematics involved in designing images of these examples. In addition to lots of computer-drawn images of snarks, physical models will be shown in various media, including ball-and-stick, origami, knitting, rubber, quilting, and (if I can pull it off!) dance. (Received April 09, 2013)

1096-A0-14 **Helaman and Claire Ferguson***, TBA. *Mathematics in stone and bronze.*

Helaman Ferguson's sculptures in stone and bronze celebrate ancient and modern mathematical discoveries. A recently completed work is the 28 foot high "Umbilic Torus SC", 20,000 lbs of silicon bronze, 55 tons of granite at Stony Brook University. Using slides and videos, Helaman and Claire trace a few of Helaman's creations from initial concept, design, graphics, diamond carving to final form. Their lectures have fascinated audiences worldwide and have sustained stimulating dialogue among multiple disciplines. (Received April 09, 2013)

1096-A0-43 **Carl Cowen***, Department of Mathematical Sciences, IUPUI, Indianapolis, IN 46202-3216. *An unexpected group.*

"What should I study to prepare myself for my future?" is a question for all students, even 'students' who are senior(!) mathematics faculty members. Part of the answer is that ANYTHING you know can turn out to be useful in mathematics! In mathematics, you should expect the unexpected! The topic for today illustrates this principle.

The problem that is the focus of this talk concerns polynomials in one variable, viewed as complex valued functions on the complex plane. In addition to the polynomials being a ring, with the ring operations being addition and multiplication of polynomials in the usual way, the polynomials are also closed under composition of functions. Clearly, the composition of a polynomial of degree m with a polynomial of degree n gives a polynomial of degree mn. In this talk, we will investigate the question "When can a given polynomial be written as the composition of two non-trivial polynomials?" For example, some polynomials of degree 15 can be written as a composition of a polynomial of degree 3 and another of degree 5, and some cannot. If we are given a polynomial of degree 15, how can we tell whether it is or is not a non-trivial composite? The answer will be given in terms of a (for me) unexpected group associated with the polynomial. (Received June 12, 2013)

1096-A0-59 **Lisa Fauci***, Tulane University, New Orleans, LA. *Explorations in phytoplankton fluid dynamics*

Phytoplankton motion in the ocean, at the scale of individual cells, involves the interaction of passive and actuated elastic structures with a surrounding fluid - a common theme in biological fluid dynamics. We present recent modeling results that shed light on the active swimming of dinoflagellates, as well as the passive motion of diatoms in shear flows . These diatoms may form chains or bear spines. In addition to examining how the flexibility and geometry of the diatoms affect their rotational dynamics, we will discuss how laboratory experiments and computational simulations are being calibrated in an effort to characterize the elastic properties of different species of chain-forming diatoms. (Received June 30, 2013)

1096-A0-60 **William Noel***, University of Pennsylvania, Phildelphia, PA. *Eureka! The Archimedes Palimpsest.*

This presentation centers on a manuscript of extraordinary importance to the history of science, the Archimedes Palimpsest. This thirteenth century prayer book contains erased texts that were written several centuries earlier still. These erased texts include two treatises by Archimedes that can be found nowhere else, The Method and Stomachion. The manuscript sold at auction to a private collector on the 29th October 1998. The owner deposited the manuscript at The Walters Art Museum in Baltimore, Maryland, a few months later. Since that date the manuscript has been the subject of conservation, imaging and scholarship, in order to better read the texts. The Archimedes Palimpsest project, as it is called, has shed new light on Archimedes and revealed new texts from the ancient world. These new texts include speeches by an Athenian orator from the fourth century B.C. called Hyperides, and a third century A.D. commentary on Aristotle's Categories. The lecture also considers more broadly the digitization of medieval manuscripts, and the impact that this will have on the study of history and literature before 1500. (Received June 30, 2013)

1096-A0-61 **Doug Ensley***, Shippensburg University, Shippensburg, PA. *Mobile math apps.*

Smartphones offer a unique opportunity to put educational technology in a student's pocket 24 hours a day. However, screen size, processor speed, and data connectivity issues present real challenges for developers, who are often focusing instead on less ubiquitous tablet technology. The Mobile Math Apps project led by Ensley and Kaskosz explores the interfaces that work well on this platform, the assessment data that tell us how students benefit from mathematics apps, and the lessons learned that will inform future development for the smartphone. (Received June 30, 2013)

1096-A0-79 **Steve Gimbel***, Gettysburg College. *Hermann Minkowski: The quiet genius.*

Hermann Minkowski was Albert Einstein.s professor in college, but the real lesson he taught Einstein came years later when he framed the geometric interpretation of the special theory of relativity and claimed that its truly revolutionary result was not its non-Newtonian mechanics, but what it said about the unified nature of space and time. Minkowski was a mathematician whose use of late 19th century geometric tools to endow physical theory with an ontological significance was a radical departure from the formalist picture of mathematics set out by Minkowski.s life-long best friend David Hilbert, but anticipated views connecting mathematics, science, and philosophy by half a century. (Received July 15, 2013)

1096-A0-497 **V. Frederick Rickey*** (fred.rickey@me.com). *The Notebooks of George Washington on Arithmetic, Geometry, Trigonometry, Logarithms and Surveying.* Preliminary report.

Just as Grant Wood portrayed Parson Weems pulling the curtain back on the life of George Washington, we shall illuminate his mathematical education using 179 pages of manuscript in Washington's youthful hand. While this material has frequently been mentioned by scholars, it has never been analyzed, so we shall present an abundance of detail. Little is known about Washington's youth, so these papers provide a way of learning about his education.

The individuals and organizations that have controlled these papers have organized and reorganized them into disorder. Is it reasonable for a thirteen-year-old to begin his mathematical education with the study of formal geometry? Could he have learned surveying before studying arithmetic and trigonometry? Using physical evidence, handwriting analysis, and mathematical context, we shall present our conjectured order of the manuscript.

This case study in mid-eighteenth century mathematical education in the American Colonies will contrast the surprising depth of his theoretical education — including logarithms and trigonometry — with his practical use of mathematics as a field surveyor. (Received September 04, 2013)

1096-A0-956 **Gavin LaRose***, Department of Mathematics, University of Michigan, 530 Church St., Ann Arbor, MI 48109-1043. *Some thoughts about teaching in the presence of technology and life.*

Does the presence of ubiquitous, networked technology doom our goal of meaningful teaching? For that matter, do the demands of our (and our students') lives, from competing classes to committee meetings, make that question moot? In this presentation I will discuss some of my own research (and "research") into these questions, offering little in the way of concrete answers but perhaps providing some snippets of personal or collective wisdom that may shed light on what some answers may be. (Received September 11, 2013)

1096-A0-2078 **Andrew G Bennett*** (bennett@math.ksu.edu). *Does Technology Help Students?*

Many years ago I started experimenting with using technology in my classes. This led me to ask the question of whether using technology was helping students learn. It took me years to realize that this is not in fact the correct question. I'll discuss the correct question and some initial work toward an answer in this talk. (Received September 17, 2013)

1096-A0-2083 **Carl W. Lee*** (lee@ms.uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506. *Teaching as Capacity Building.* Preliminary report.

Drawing on some of my personal experiences, I will reflect on teaching as a capacity-building endeavor. This includes promoting mathematical practices of students in mathematics courses; developing institutional capacity, such as cross-college collaboration to address issues in the training of future teachers; and regional projects, such as the NSF ACCLAIM Center for Learning and Teaching focusing on rural issues in mathematics education, particularly in the central Appalachian region. (Received September 17, 2013)

1096-A0-2787 **Victor Donnay***, Bryn Mawr College, Bryn Mawr, PA. *Sustainability + Serendipity = Math Awareness Month 2013*

As Chair of the Planning Committee for Mathematics Awareness Month 2013, whose theme was "The Mathematics of Sustainability," I will discuss the process of developing the materials for Mathematics Awareness Month. Serendipity played an unexpected role in the process of commissioning essays that explained how mathematics gets used in sustainability from a wide range of authors. I will also share my experiences incorporating issues of sustainability into teaching, at a variety of levels, including the use of service learning projects in which students used their math skills to green their school or community. (Received October 16, 2013)

The Unreasonable Effectiveness of Modern Mathematics

1096-AB-146 **Robert Ghrist*** (ghrist@math.upenn.edu). *The Unreasonable Effectiveness of Sheaf Cohomology in Networks.* Preliminary report.

The most abstract branches of mathematics inexorably transform into tools for concrete applications. This talk will gently survey sheaves and sheaf cohomology (tools that many mathematicians find intimidating) and argue that these powerful methods are perfectly suited to contemporary problems in data analysis over networks. Applications to network optimization, sensor networks, and more will be given. (Received August 09, 2013)

1096-AB-352 **Daniel K Nakano*** (nakano@math.uga.edu), Department of Mathematics, University of Georgia, Athens, GA 30602. *The Unreasonable Effectiveness of Representation Theory and the P vs NP Problem.*

In this talk I will start with the basics of representation theory which is a subject that arose in the late 19th century in the work of Frobenius. Examples will be presented, in particular, for the case for GL_n-representations over the complex numbers.

The $P = NP$ problem is one of the most famous problems in theoretical computer science and mathematics. The Geometric Complexity Theory (GCT) program introduced by Mulmuley and Sohoni provides an amazing approach towards this problem via algebraic geometry and representation theory. With the background laid out in the first part of the talk, I will outline parts of the GCT strategy to show that $P \neq NP$. (Received August 29, 2013)

1096-AB-455 **Bernd Sturmfels*** (bernd@berkeley.edu), Department of Mathematics, University of California, Berkeley, CA 94708. *The Euclidean Distance Degree.*

The nearest point map of a real algebraic variety with respect to Euclidean distance is an algebraic function. For instance, for varieties of low rank matrices, the Eckart-Young Theorem states that this map is given by the singular value decomposition. We present work with Jan Draisma, Emil Horobet, Giorgio Ottaviani and Rekha Thomas on nearest point maps from the perspective of computational algebraic geometry. The Euclidean distance degree is the number of critical points of the squared distance to a point outside the variety. Our aim is to compute this number for varieties seen in applications. (Received September 03, 2013)

1096-AB-519 **Alice Silverberg*** (asilverb@uci.edu), Mathematics Department, UCI, Irvine, CA 92697-3875. *The Unreasonable Effectiveness of Number Theory in Cryptography.*

Suppose that your doctor's office uses a third party vendor to store all its medical records, encrypted, on a remote server. Now suppose that your doctor needs to perform some calculations on that data. Downloading the encrypted file and then decrypting it in order to do computations might not be feasible or reasonable. Fully Homomorphic Encryption allows the untrusted third party to compute with the (encrypted) data, without learning anything about the data, or even about what calculations are being performed. How to do this was a major open problem in cryptography, which was recently solved by Craig Gentry using algebraic number theory. This talk will give an introduction to Fully Homomorphic Encryption and how number theory is used to achieve it. (Received September 05, 2013)

The Continuing Influence of Paul Erdős in Number Theory

1096-AC-806 **Kevin B Ford** (ford@math.uiuc.edu), Department of Mathematics, 1409 West Green Street, University of Illinois at Urbana Champaign, Urbana, IL IL 61801, **Florian Luca*** (fluca@matmor.unam.mx), Instituto de Matematicas, UNAM, 04510 Mexico City, Mexico, and **Carl B Pomerance**, Mathematics Department, Dartmouth College, Hanover, NH 06755. *Counting integers with special properties.*

Take your favorite infinite set of positive integers (primes, squares, Fibonacci numbers) and count how many of them are below a certain bound x. The answer is easy to get in some cases (like the case of the squares) and can be quite difficult in others (like in the case of primes). In my talk, I will mention a few of Paul Erdos' favorite numbers to count, like the numbers below x^2 arising as a result of a multiplication of two numbers each at most x, as well as the ranges of the Euler function $\phi(n)$ and its lesser studied cousin the Carmichael function $\lambda(n)$. The number $1-(1+\ln\ln 2)/\ln 2$ appears in a mysterious way in some of these unrelated problems. Most of the talk is expository and based on known results but we will mention some recent results obtained in joint work with K. Ford and C. Pomerance. (Received September 10, 2013)

1096-AC-823 **Ron Graham*** (graham@ucsd.edu), La Jolla, CA 92093. *Paul Erdős and Egyptian Fractions.* Preliminary report.

One of Paul Erdős' earliest mathematical interests was the study of so-called *Egyptian fractions*, that is, finite sums of distinct fractions having numerator 1. In this talk we survey various results in this subject, many of which were motivated by Erdős' problems and conjectures on such sums. (Received September 10, 2013)

1096-AC-1100 **Melvyn B. Nathanson*** (melvyn.nathanson@lehman.cuny.edu), Department of Mathematics, Lehman College (CUNY), Bronx, NY 10468. *Problems and results in additive number theory.*

This will survey some of Paul Erdos's work on bases of finite order in additive number theory, and review the current status of open problems in the field. Special attention will be paid to extremal problems, and, in particular, to thin bases, minimal bases, and maximal nonbases. (Received September 12, 2013)

1096-AC-1436 **Michael Filaseta*** (filaseta@math.sc.edu), Mathematics Department, University of South Carolina, Columbia, SC 29208. *Applications of the prime factorization of the product of consecutive integers to polynomials.*

In 1934, Erdős published one of his first few papers on an elementary proof of a theorem of Sylvester stating that, for every positive integer k, the product of k consecutive integers $> k$ is always divisible by a prime $> k$. Over forty years later, in 1975, Erdős and Selfridge established that the product of two or more consecutive positive integers is never a power, that is never of the form m^k where m and k are integers with $k > 1$. There have been a number of variations of these results since, and in this talk we will discuss some of these and focus largely on several ensuing applications to the irreducibility of polynomials and to a recent result on the Galois group associated with the generalized Laguerre polynomials. (Received September 15, 2013)

1096-AC-1614 **Andrew Granville*** (andgranville@gmail.com), University de Montreal, Pavillon Aisenstadt, Dept de mathematiques et de statistiques, CP 6128 Succursale Centre-Ville, Montréal, Quebec. *The pretentious approach to analytic number theory.*

Paul Erdos was the master of ad hoc analytic techniques in number theory. Yet there was method to his ad hockery, and our quest to give a pretentious approach to the subject is, in a sense, a desire to combine and codify these methods, due both to Erdos and to others. In this talk we will outline how one can prove Linnik's Theorem by such elementary methods, as an illustration of the power of such techniques. This is joint work with Adam Harper and K Soundararajan. (Received September 16, 2013)

1096-AC-1698 **Mits Kobayashi*** (mkobayashi@csupomona.edu), Cal Poly Pomona, Department of Mathematics and Statistics, Pomona, CA 91768. *Erdős and the abundant numbers.*

As early as 1934 Erdős turned his attention to the abundant numbers, giving an elementary proof of the result of Davenport that the natural density of abundant numbers exists. This was done by estimating the number of primitive abundant numbers up to a given bound. We will focus on the progress made in the study of primitive abundant numbers and the existence of densities defined by multiplicative functions, much of which was due to Erdős himself. (Received September 16, 2013)

Uniform Distribution, Discrepancy, and Related Fields

1096-AD-223 **Michael T Lacey*** (lacey@math.gatech.edu), Mathematics, Georgia Tech, Atlanta, GA 30332. *The Small Ball Inequality.* Preliminary report.

The small ball inequality has formulations in probability theory, discrepancy, and approximation theory. It has a combinatorial expression as an inequality on Haar functions in high dimensions: One sums Haar functions, adapted to a cubes of a fixed volume, in the unit cube in n dimensions. The orthogonality of the Haar functions provides an easy lower bound on the L^∞ norm of the sum. The small ball inequality is an improvement on this easy bound. It is true in dimension 2, a Theorem of Talagrand, and is conjectural in higher dimensions, although there are better than trivial estimates known, due to Bilyk, Vagharshakyan, and the speaker. We will survey the small ball inequality, its ranges of applications, what is known, and why it hard. (Received August 21, 2013)

1096-AD-1032 **E B Saff*** (edward.b.saff@vanderbilt.edu), Center for Constructive Approximation, Department of Mathematics, Vanderbilt University, Nashville, TN 37240. *Discretizing Manifolds with Minimal Energy.*

The problem of finding configurations of points that are optimally-distributed on a set appears in a number of guises including best-packing problems, coding theory, geometrical modeling, statistical sampling, radial basis approximation and golf-ball design (i.e., where to put the dimples). This talk will focus on classical and recent results concerning geometrical properties of N-point configurations $\{x_i\}_{i=1}^N$ on a compact metric set A (with metric m) that minimize a *weighted Riesz s-energy* functional of the form

$$\sum_{i \neq j} \frac{w(x_i, x_j)}{m(x_i, x_j)^s},$$

for a given 'weight' function w on $A \times A$ and a parameter $s > 0$. By an appropriate choice of w, one can generate a quasi-uniform sequence of configurations that also has (as $N \to \infty$) a prescribed positive continuous limit distribution with respect to Hausdorff measure (surface area on 2-dimensional compact manifolds). (Received September 12, 2013)

1096-AD-1173 **Vladimir N Temlyakov*** (temlyakovv@gmail.com), Math. Dept., University of South Carolina, Columbia, SC 29208, and **V.N. Temlyakov**, University of South Carolina and Steklov Institute of Mathematics. *Multivariate numerical integration*

We discuss a construction of good cubature formulas for multivariate numerical integration. These cubature formulas are near optimal for classes of functions with bounded mixed derivative. They are also universal in the sense that they are near optimal for all anisotropic Sobolev-Nikol'skii smoothness classes. Construction of such cubature formulas is closely connected with deep problems in number theory. Number theoretic methods are used for obtaining upper estimates of optimal errors which means the construction of concrete good cubature formulas. For this purpose different methods are used, beginning with sufficiently elementary methods for investigating Fibonacci and Korobov cubature formulas and finishing with cubature formulas based on algebraic properties of real roots of irreducible polynomials. Research was supported by NSF grant DMS-1160841 (Received September 13, 2013)

1096-AD-1219 **Art B. Owen*** (owen@stanford.edu), Department of Statistics, Sequoia Hall, Stanford, CA 94305. *Monte Carlo, Quasi-Monte Carlo and randomized Quasi-Monte Carlo.*

Monte Carlo (MC) sampling is used to solve problems in virtually every branch of science and engineering, even problems without genuine randomness. MC involves simulating random quantities, starting with independent uniform random variables.

Simulating uniform random variables can be viewed as placing points at random inside a box. Why not just pick some really good points? With n observations MC typically has error $O(n^{-1/2})$, a slow rate of improvement. Spreading the points more evenly is known as quasi-Monte Carlo (QMC) sampling. QMC has typical error $O(n^{-1+\epsilon})$. Ignoring constants and regularity conditions, this is almost as good as squaring the sample size.

While QMC increases accuracy it loses one of the benefits of MC. MC lets us estimate error by repeated sampling. QMC is deterministic, so repeating it gives the same answer and provides no error estimate.

Randomized QMC(RQMC) uses independent random replicates of points all with the same QMC property, allowing replication based error estimates. Surprisingly, some RQMC methods reduce the error rate to $O(n^{-3/2+\epsilon})$. Where MC randomizes, QMC de-randomizes, then RQMC re-randomizes. Each step brings an improvement. MC, QMC and RQMC point sets are all designed via the algebra of finite fields. (Received September 13, 2013)

1096-AD-1599 **Alex Iosevich*** (iosevich@math.rochester.edu), 145 Dunrovin Lane, Rochester, NY 14618. *Discrepancy estimates in continuous, discrete and arithmetic settings.* Preliminary report.

We shall discuss discrepancy estimates arising in connection with the Falconer distance problem in geometric measure theory, geometric combinatorics in vector spaces over finite fields and discrete analogs in the Euclidean space. (Received September 16, 2013)

1096-AD-1924 **Artur Avila**, **Dmitry Dolgopyat*** (dmitry@math.umd.edu), **Eduard Duriev** and **Omri Sarig**. *Geometric proof of the Central Limit Theorem for Kronecker sequences.*

We present a geometric proof of the following theorem of Jozsef Beck. Let α be a quadratic irrational. Denote $D(n)$ =Card$(0 \leq j < n$ such that $\{\alpha j\} < 1/2) - n/2$ where $\{\dots\}$ denotes the fractional part. Choose n uniformly distributed between 1 and N. Then there are constants A and B such that $(D(n) - A \ln N)/(B\sqrt{\ln N})$ converges to the standard Gaussian as $N \to \infty$. (Received September 16, 2013)

Graphs Don't Have to Lie Flat: The Shape of Topological Graph Theory

1096-AE-513 **Mark Ellingham*** (mark.ellingham@vanderbilt.edu). *Embeddings of graphs with hamilton cycle faces.*

The genus problem for graphs involves embedding a graph (drawing it without edge crossings) in a surface that is as simple as possible (has minimum genus). Minimum genus embeddings generally have faces that are small, triangles if possible. However, in order to find minimum genus embeddings for certain families of graphs it turns out to be useful to study embeddings of other families of graphs in which the faces are large. In particular, we study embeddings in which the boundary of every face is a hamilton cycle, a cycle that goes through every vertex. In this talk we survey what is known about hamilton cycle embeddings of graphs, including our recent results with Justin Schroeder that use latin squares and algebraic construction techniques (voltage graphs).

Many of the results discussed are from joint projects with Justin Schroeder, Chris Stephens, Adam Weaver and Xiaoya Zha. (Received September 05, 2013)

1096-AE-1737 **Joan P Hutchinson*** (hutchinson@macalester.edu), Department of Mathematics, Macalester College, Saint Paul, MN 55105. *Coloring graphs on surfaces, contrasted with coloring on the plane.* Preliminary report.

The celebrated Four Color Theorem and Thomassen's 5-list Coloring Theorem for graphs on the plane point the way to other coloring questions on the plane and, even more, to such questions about graphs embedded on nonplanar surfaces. For example, what happens when some vertices of a graph are precolored or when some vertices receive lists of smaller size? Such questions are often much harder to answer on the plane than on nonplanar surfaces. And what happens when the two points of view are combined by considering "locally planar" graphs on surfaces (that is, graphs embedded on nonplanar surfaces with all noncontractible cycles sufficiently long so that locally they appear to be planar)? To what extent do these locally planar graphs exhibit coloring properties of planar graphs or of nonplanar graphs? We will discuss these questions with lots of colorful graphics. (Received September 16, 2013)

1096-AE-1947 **Joanna A. Ellis-Monaghan*** (jellis-monaghan@smcvt.edu), Saint Michael's College, One Winooski Park, Colchester, VT 05439. *Polynomials of graphs in surfaces.*

Historically, graph polynomials have had either abstract or plane graphs as their domains. Recently however, graph polynomials have taken on a topological flavor, with several classical polynomials being extended to graphs embedded in surfaces. These include the topological graph polynomials of Las Vergnas, Bollobas-Riordan, Krushkal, Penrose, and the topological transition polynomial. We will survey these polynomials, the interrelations among them, and new results on how they encode topological information about embedded graphs. (Received September 16, 2013)

1096-AE-2761 **Michael J. Pelsmajer*** (pelsmajer@iit.edu). *Superfluous crossings.*

Usually the first goal when drawing a graph is to avoid edge crossings. Under the right conditions, certain types of crossings can be removed from a drawing. Our prototypical example is the following theorem of Hanani and Tutte:

If every pair of edges crosses an even number of times in a graph drawing, then the graph can be redrawn with no crossings.

There has been a lot of exciting work of a similar flavor in recent years. We will survey the field, with an emphasis on proof techniques and open problems. (Received September 18, 2013)

Mathematics and Effective Thinking

1096-AF-353 **David Bressoud*** (bressoud@macalester.edu). *Harnessing the Flow of History.* Preliminary report.

I will use the example of Calculus instruction to demonstrate how the history of mathematics can be used to motivate students, to identify difficult concepts, and to provide an organizational structure that facilitates the organization of their knowledge. (Received August 29, 2013)

1096-AF-425 **Stan Yoshinobu*** (styoshin@calpoly.edu), 2230 Exposition Drive Unit 30, San Luis Obispo, CA 93401. *Supporting Math Instructors to Teach in Ways that Foster Effective Thinking.*

Uptake of empirically validated teaching methods is low, despite evidence and awareness of the benefits of student-centered methods, such as inquiry-based learning. One of the questions that will be addressed is, "How could the profession support individual instructors to improve effective thinking in their mathematics courses?" An approach using a portfolio of strategies to support instructors to overcome some of the obstacles they face will be discussed in this talk. The strategies include intensive workshops, mentoring, small grants, and perhaps most importantly building a community. (Received September 03, 2013)

1096-AF-636 **Edward B. Burger*** (burger@southwestern.edu), Office of the President, Southwestern University, P.O. Box 770, Georgetown, TX 78627. *A 21st century curriculum that raises education to a global maximum.*

Here we will reflect on the practical change required throughout our courses and our curriculum to realize the two paramount goals of education: Engaging Minds and Transforming Lives. Our perspective will straddle between philosophical and concrete categories. Might this duality leave us in the vulnerable position in which our head is in the clouds while our feet are planted firmly in cement? Perhaps, but that would still be less ineffective than our current state of higher education. All are welcome to join the thought provoking conversation to further provoke thought. (Received September 08, 2013)

1096-AF-641 **J Michael Pearson*** (pearson@maa.org), MAA, Washington, DC 20036. *Context and Evidence: Aligning Goals and Practice in the Undergraduate Mathematics Program.*

The last 40 years have seen tremendous growth in undergraduate enrollment, coupled with a change in the profile of the student population. Students come to us with more varied backgrounds, and more varied goals, than ever before. At the same time, and to a large extent driven by technology, mathematical tools play key roles in more disciplines and careers than ever before. But the specific quantitative tools vary widely, and the standard undergraduate curriculum does not adequately prepare most students to appreciate, much less use, quantitative tools outside of the mathematics classroom.

The MAA is in a unique position to bring diverse perspectives together to develop recommendations for both current practice and future work to improve the undergraduate program. I'll share some highlights of the current work of CUPM on a new Curriculum Guide, and some new initiatives that I think can help improve both the content and delivery of undergraduate mathematics. (Received September 08, 2013)

1096-AF-695 **Carol Schumacher*** (schumacherc@kenyon.edu). *What is the Definition of Definition? and Other Conundrums.*

Helping our students think like mathematicians should be at the center of every class we teach. The particular topic will affect which parts of thinking mathematically we might address, but our should be to turn out students who can bring mathematical reasoning to bear in the context of the course material and beyond. In order to help our students think like mathematicians, we teachers must think deeply about what is going on in our students' heads. But this also takes an unusual amount of self-reflection. We need to understand how we think about things. Unfortunately, thinking mathematically is often something that comes naturally to people who eventually get Ph.D.'s in mathematics. Thus we have no idea how we learned to think this way, and we are often not even aware of how much is really going on in our own heads when we attack a mathematical question. The talk will discuss several such conundrums and illustrate ways to help our students become more effective thinkers. (Received September 09, 2013)

1096-AF-716 **Sandra Laursen***, Ethnography & Evaluation Research, University of Colorado Boulder, 580 UCB, Boulder, CO 80309-0580. *Inquiry and Effective Thinking: Evidence from a Multi-Site Educational Research Study.*

Educational research across the natural and mathematical sciences supports the use of student-centered, active learning methods to enhance students' learning, motivation and persistence in the field. Our group carried out a large, mixed-methods study of inquiry-based learning (IBL) as implemented in some 40 undergraduate mathematics courses on four university campuses. Despite variability in instructors' approach to and skill with IBL, the results show benefits to students, especially for some groups that are often under-served by traditional lecture-based approaches, including women and lower-achieving students. First-year and less mathematically experienced students also benefited particularly. Yet there was no evidence of negative consequences of IBL for other students, who also made gains greater than their non-IBL peers. The positive outcomes for students were linked to classroom practices that emphasized deep engagement with mathematical ideas and collaborative exploration of these ideas. In this session, I will highlight evidence from our study that IBL supports development of "effective thinking" of two types: that which has an effect on the problem, and that which has an effect on the thinker. (Received September 09, 2013)

1096-AF-750 **Jodi Cotten*** (jodi.cotten@sunywcc.edu), Westchester Community College, Technology Building - 153, 75 Grasslands Road, Valhalla, NY 10595. *Hearts and Minds: Waging the Battle to Win Over Liberal Arts Students.* Preliminary report.

Convincing liberal arts students that mathematics and thinking mathematically is useful in practice in real-life situations can sometimes seem like combat! They come into the classroom with biases and pre-conceived notions that they are poor at math if they do well in humanities and social sciences and that even if they could master mathematical skills, these skills serve no purpose in their fields and in their day-to-day lives. They may become anxious ("Why do I have to take this class? I can't do math."), or they may project negative attitudes ("I don't see why I have learn this when I'll never use it."). How do we, as teachers, challenge these notions and help our students learn to love the subject as we do? While we may not turn every student into a mathophile, I have had success teaching students of every stripe in online and face-to-face courses how to master, appreciate, and enjoy mathematics. Please join me to share successful strategies on how to win over native liberal arts students. Win their hearts and their minds will follow! (Received September 09, 2013)

1096-AF-801 **Katherine Socha*** (ksocha@mathforamerica.org). *On The Elements of Style.*

"Do cats eat bats?" "Do bats eat cats?" Order matters. *"When nine hundred years old you reach, look as good you will not."* Order does not matter.

"In the sentence the student should find the law of unity, of continuity, of proportion, of order." Order matters - but so do other elements of style. Effective thinking, embodied by effective use of language, is inherently mathematical; both effective thinking and mathematics are inherently stylish. We will explore examples from fiction and non-fiction to see the mathematical thinking that underlies effective (and elegant) communication of ideas. (Received September 10, 2013)

1096-AF-861 **Paul Zorn*** (zorn@stolaf.edu). *Mathematical writing and effective thinking.*

Writing and mathematics are both hard, and mathematical writing is doubly difficult. Mathematical language and symbols are formal, precise, and sometimes forbidding, and naturally so: communicating technical ideas and fine distinctions inevitably requires extra linguistic effort. Parsing the ϵ–δ definition of uniform continuity of a function on an interval, for example, is a difficult linguistic task in its own right, mathematical subtleties aside. We mathematicians realize, for instance, that "each" and "every" can mean the same thing in such contexts, and that "whenever" can signal universal quantification rather than any reference to time. Students, by contrast, need to develop these intuitions with experience.

Grappling with mathematical language is undeniably, and perhaps inevitably, tough for students. But doing so is essential to deep mathematical understanding, clear communication, and effective thinking. I'll suggest some ways of encouraging and promoting that encounter.

The good news is that this hard mathematical and linguistic work pays off, both in mathematics itself and in other areas of academic study and, I'll claim, in deepening and enriching our intellectual lives. (Received September 10, 2013)

1096-AF-1235 **Francis Edward Su*** (su@math.hmc.edu), Department of Mathematics, Harvey Mudd College, Claremont, CA 91711. *Thinking about Mathematics and Meaning.*

It is a uniquely human endeavor to reflect on the things of this world and the relationships between them, and to seek meaning in the patterns we encounter. In mathematics, we not only reflect on but we *create* things and relationships between them by endowing them with meaning. So we can teach effective thinking by helping people deeply engage the meaning of every idea they encounter, in mathematics and in life. (Received September 13, 2013)

1096-AF-1443 **Deborah J Bergstrand*** (dbergst1@swarthmore.edu), Department of Mathematics & Statistics, Swarthmore College, Swarthmore, PA 19081. *Think Before You Speak: using presentations and prepared questions to promote effective thinking.*

Some students ask good questions, others ask lame ones. Some students present their work clearly and concisely, others are like spilled water on the page or at the board. Helping students learn to ask good questions and present their work well can also develop their broader thinking skills. Along the way, they may gain a better understanding of mathematics. In this talk, I will discuss using Moodle to have students submit questions on assigned reading and two formats for student presentations. (Received September 15, 2013)

Six Crash Courses on Mapping Class Groups

1096-AG-879 **Andrew Putman*** (andyp@rice.edu), Department of Mathematics, Rice University, MS 136, 6100 Main St., Houston TX 77005, Houston, TX 77005. *Introduction to the mapping class group.*

This will be a basic introduction to the mapping class group. I will start by motivating the study of this group through some basic constructions in 3-manifold theory and (possibly) algebraic geometry. I will then give an overview of the rudiments of the subject, including discussions of the basic examples of the torus and the annulus, Dehn twists, finite-order elements, and other related topics. (Received September 10, 2013)

1096-AG-910 **Johanna Mangahas*** (`mangahas@math.brown.edu`). *The Nielsen-Thurston Classification of Mapping Classes.*

In this course we explore the anatomy of individual elements of mapping class groups. The mapping classes of a torus can be understood as area-preserving linear maps whose behavior depends decisively on whether the map fixes an irrational direction, a rational direction, or whether some iterate of the map is the identity. The Nielsen-Thurston classification generalizes this trichotomy to mapping classes of any surface: the corresponding types are pseudo-Anosov, reducible, or periodic, respectively. We'll focus especially on pseudo-Anosov mapping classes, and see how stretch factors and certain structures on the surface play the same role as eigenvalues and eigenvectors in the torus case (Received September 11, 2013)

1096-AG-1606 **Spencer Dowdall***, Department of Mathematics, 1409 W Green Street, Urbana, IL 61801. *Pseudo-Anosovs and the dynamics of surface homeomorphisms.*

This talk will survey various aspects of the dynamics of pseudo-Anosov homeomorphisms. We will focus on the stretch factor (or dilatation) of a pseudo-Anosov and give various interpretations of this number via, e.g., intersection numbers of curves, lengths of curves, and length in moduli space. Moreover, the spectrum of attainable stretch factors is discrete, and every stretch factor is an algebraic integer. Time permitting I will discuss other dynamical properties such as ergodicity and the existence of dense orbits. (Received September 16, 2013)

1096-AG-2084 **Tara Brendle*** (`tara.brendle@glasgow.ac.uk`), School of Mathematics & Statistics, 15 University Gardens, University of Glasgow, Glasgow, G12 9PX, United Kingdom. *Finite generation of the mapping class group and the complex of curves.*

A surface homeomorphisms supported on an annulus is known as a Dehn twist. It turns out these small, simple elements are the basic building blocks of the entire mapping class group of any surface, that is, Dehn twists generate the group. In other words, every homeomorphism of a surface can given by a finite sequence of Dehn twists (up to isotopy), much the same as one can solve any Rubik's cube puzzle by a finite sequence of twists. In this talk we will describe Dehn twists, and, as a first step, show that the (infinite) set of all Dehn twists generates the mapping class group. We will then introduce the complex of curves of a surface, and explain how to use this powerful combinatorial tool to show that in fact a finite set of Dehn twists suffices to generate. Consequences of this fundamental theorem include the fact that the mapping class group (for genus at least 3) is perfect, that is, its abelianization is trivial. (Received September 17, 2013)

1096-AG-2694 **Christopher J Leininger*** (`clein@math.uiuc.edu`), 1409 W. Green St., urbana, IL 61802. *Hyperbolic geometry and surface bundles.*

A surface bundle is completely determined by the associated monodromy from the fundamental group of the base to the mapping class group of the fiber. Therefore, we stand to gain much geometric information about surface bundles by studying the geometric properties of the mapping class group of a surface.

In this lecture we will discuss geometric aspects of the mapping class group and describe a fascinating connection between the coarse geometry of a surface bundle and the geometry of actions of the mapping class group. This will begin with some preliminary discussion of some of the canonical spaces on which the mapping class group acts, after which we will explain the connection between coarse hyperbolicity of surface bundles and the notion of convex cocompactness for subgroups of the mapping class group as defined by Farb and Mosher. We end with a discussion of some of the open questions and partial results. (Received September 18, 2013)

1096-AG-2744 **Dan Margalit*** (`margalit@math.gatech.edu`). *Characteristic classes for surface bundles.*

A characteristic class for a vector bundle is some data that describes how twisted the vector bundle is. The simplest instance is that an open annulus has trivial characteristic classes and an open Mobius band has nontrivial characteristic classes. Characteristic classes are useful because they are computable, and because they help us tell vector bundles apart (how else can we distinguish the tangent bundle of, say, a sphere from the trivial bundle?) It turns out that there is a complete list of all characteristic classes; they correspond to cohomology classes of a space called the Grassmannian. In this talk we will describe this classical theory and show how it transfers to the case of surface bundles (the fiber over each point is a surface instead of a vector space). Again the characteristic classes describe how twisted the bundle is and again the characteristic classes correspond to the cohomology classes of some other known object, in this case the mapping class group. The characteristic classes we do understand have some remarkable symmetries. However, unlike the vector bundle case, we are far from having a complete list. I will survey what is known and given an idea of the vastness of the uncharted territory. (Received September 18, 2013)

1096-AG-2754 **Benson Farb*** (farb@math.uchicago.edu), Math Dept., University of Chicago, 5734 S University Ave., Chicago, IL 60637. *Open problems on mapping class groups and related topics.*

In this talk I will discuss some open problems about mapping class groups. I will try to explain the motivation for each problem, the key examples, and what we know so far. I will emphasize connections with and applications to other areas of mathematics. (Received September 18, 2013)

Assessing Quantitative Reasoning and Literacy

1096-B1-310 **Rodney E McNair*** (rmcnair@desu.edu), Department of Mathematical Sciences, Delaware State University, Dover, DE 19901. *The Need to Assess Quantitative Literacy in the Major.*

Current efforts to assess QL at the general education level may send the wrong message and confuse the role of QL in the major. Quantitative Literacy (QL) lives and breathes in discussions about measuring, predicting, and managing change. Everything changes. Understanding change is a central component of every discipline and so QL is a central part of every discipline. QL is as much a part of chemistry, biology and psychology as are chemicals, cells, and emotions. QL has a direct relationship to what it is that students are (or are not) learning to do in their major. I argue that as QL increases so too does understanding of the content in the major. Mathematics is developed as we attempt to understand change and as we attempt to make QL arguments more precise. Thus QL has a significant role in the development of mathematics. QL is not only a general education skill that needs to be applied in the discipline. QL is a central component of the discipline and so should be taught and assesses as such. A discipline centered approach is needed to fully assess QL. (Received August 27, 2013)

1096-B1-1093 **Victor I Piercey*** (piercev1@ferris.edu), Ferris State University, Department of Mathematics, 820 Campus Drive ASC 2021, Big Rapids, MI 49307. *Assessment in an inquiry-based quantitative reasoning course for business students.* Preliminary report.

Quantitative Reasoning for Business is an inquiry-based learning course for business majors. Student learning is assessed in a variety of ways, including portfolios, unit capstones, and mastery-learning assignments. In this talk, I will discuss these assessment tools and any changes under consideration. (Received September 12, 2013)

1096-B1-1148 **Eric Gaze*** (egaze@bowdoin.edu), Brunswick, ME 04011. *Results from an NSF TUES Quantitative Reasoning Assessment Project.*

The Quantitative Literacy and Reasoning Assessment (QLRA) project is a NSF TUES Type I pilot project (DUE 1140562). A primary goal of the project was to create a non-proprietary QLR instrument by combining the existing Bowdoin, Colby-Sawyer, and Wellesley tests. The QLRA test has been piloted at over 30 schools across the country the past two years. Results have been used to refine the test and begin the creation of a national baseline of students' QR abilities from both 2-year and 4-year schools. A web portal has been developed for schools wishing to participate in the project and administer the QLRA instrument on their campuses. This talk will discuss the development of the test, lessons learned and results. (Received September 13, 2013)

1096-B1-1643 **Stuart Boersma*** (boersmas@cwu.edu) and **Dominic Klyve** (klyved@cwu.edu). *Measuring Habits of Mind: Toward a Prompt-less Instrument for Assessing Quantitative Literacy.*

In this study, we offer a new "prompt-less" instrument for measuring students' habits of mind in the field of quantitative literacy. The instrument consists of a series of questions about a newspaper article the students read. The questions do not explicitly solicit quantitative information; students' habit of mind is assessed by their use of quantitative reasoning even when it is not asked for. Students' answers were graded according to a modified version of the Quantitative Literacy Assessment Rubric (QLAR). We applied the instrument and rubric to assess pre- and post-intervention habits of mind in opportunistic samples of two cohorts of students: the general (non-STEM) student body and (non-STEM) honors students at Central Washington University. (Received September 16, 2013)

1096-B1-2118 **Semra Kilic-Bahi*** (skilic-bahi@colby-sawyer.edu), 541 Main St., New London, NH 03257. *QL Across the Curriculum at Colby-Sawyer College.*

This talk will focus on the assessment and evaluation of the QL Across the Curriculum initiative at Colby-Sawyer College. This initiative started in 2007 and was largely supported by an NSF Due grant, #0633133. (Received September 17, 2013)

1096-B1-2153 **Cinnamon Hillyard***, hillyard@carnegiefoundation.org, and **Eugene Milman** and **Duane Benson**. *A Collaborative Approach to Assessing Quantitative Literacy within Carnegie's Quantway Pathway for Developmental Mathematics.*

The Carnegie Foundation for the Advancement of Teaching created the quantitative reasoning course Quantway®as an alternative to the traditional beginning algebra and intermediate algebra developmental math courses found at many colleges. This mathematics pathway has proven to provide three times the success in half the time for getting students through their math requirements in order to purse a college degree. A large part of this success can be credited to the use of a Networked Improvement Community (NIC) working around a common problem to develop and improve the quantitative reasoning curriculum and assessments. In this presentation, we will describe how we have developed assessments to match the quantitative reasoning central to Quantway. In particular, we will focus on our common online and final assessments that all NIC colleges use in their sections of Quantway. We will talk about the success and challenges of using our current items (many of which are multiple choice) to measure quantitative literacy, how the items are developed as a collaborative process using NIC faculty members, and our plans to expand our assessments to more open ended items that can be efficiently and reliably scored across multiple institutions. (Received September 17, 2013)

1096-B1-2346 **Robert J. Krueger*** (rkrueger@csp.edu). *Assessing Quantitative Reasoning in Introduction to Probability and Statistics.*

As the world becomes more inundated with data, the use and misuse of that data is becoming more common. At Concordia University, St. Paul, a small Christian liberal arts based university, Introduction to Probability and Statistics has been the top course for assessing Quantitative Reasoning. University wide rubrics are used to measure student learning outcomes that include translating, analyzing, and interpreting data, as well as supporting conclusions. Successes and struggles will be shared. (Received September 17, 2013)

1096-B1-2424 **Maura B. Mast*** (maura.mast@umb.edu). *Three Approaches to Assessment in the Quantitative Reasoning Classroom.*

For more than a decade, the University of Massachusetts Boston has offered a quantitative reasoning course as part of its general education program. Based on assessment and faculty feedback, the course has evolved over this time. Students in the current version of the course use common sense, common knowledge and relevant mathematics and technology in real contexts to understand quantitative information and solve problems. As the course has evolved, the assessment of the course has also evolved. The original assessment consisted of student surveys designed to collect student reflections on how they were using the course material and approach. We then introduced holistic grading of common final exam questions to assess student learning outcomes. With funding from a National Science Foundation grant, we began to administer pre- and post-semester surveys (adapted from the Dartmouth Mathematics Across the Curriculum Project) to capture attitudinal change. In this talk we present an overview of these three approaches and their merits. (Received September 17, 2013)

1096-B1-2626 **Jill Bigley Dunham***, 401 Rosemont Ave, Frederick, MD 21701, and **Betty Mayfield** (mayfield@hood.edu), 401 Rosemont Ave, Frederick, MD 21701. *Standardizing assessment across QL courses.*

Here at Hood College, we have been examining our core requirement in quantitative literacy as our college is updating the core curriculum. We are working to develop a standard set of assessment criteria for our QL courses, which include an introductory statistics course, a liberal-arts mathematics course, and two content-specific courses, The Mathematics of Games and Sports and The Mathematics of Democracy. In order to assess these differing courses, we have developed a set of QL learning objectives, created course-based assessments based on those learning objectives, and administered pre- and post-course attitudinal surveys. We will discuss our methodologies, results, and future assessment plans. (Received September 18, 2013)

Assessing Student Learning: Alternative Approaches

1096-B5-143 **Gail M. Tang*** (gtang@laverne.edu), University of La Verne. *Spying on your students (mathematically, of course).* Preliminary report.

There is a significant move towards promoting collaborative work in math classes. Often there are two issues with this pedagogy. One, assessing students' learning and understanding during group work is logistically difficult for us as instructors, whose attention is split between several groups. How can we accurately assess each student's contributions? How can we accurately assess learning and understanding based on the submitted written work?

The second is a comfort issue for the students: students who are extroverted can work well in groups, but those who are introverted can feel intimidated by groupwork. This can lead to limited participation and thus inaccurate assessments. How can we accurately assess the level of mastery of the shy students? How can we give them a voice so their thinking becomes visible?

In this talk, I will discuss two techniques to address these questions. One uses a pen in its most familiar state, and is fun and easy to implement. I will show examples from classes for non-majors and science majors. The other method uses an electronic Livescribe pen, which you or students must purchase. This method has been used in math courses for science majors. In both scenarios, instructors capture student discussions, misconceptions, and participation. (Received August 08, 2013)

1096-B5-167 **Brian J Winkel*** (brianwinkel@hvc.rr.com), 26 Broadway, Cornwall, NY 12518. *Active Assessment and Group/Individual Final Exams.* Preliminary report.

We present and discuss an approach we have used in a mathematical modeling course in which in-class assessment through overlooking small group work, presentations, routine "board" work in which students offer up their ideas simultaneously for teacher and peer feedback. The culmination is in a final exam in which students are assigned "randomly" to teams of three, given their own classroom, and work on a common modeling scenario coupled with individual additional accountability question(s), and individual write-ups. Students show their stuff, always. Making it easy to assess and a good experience for students and faculty. We have used similar techniques in an "at risk" entry level course and we point out the richness possible with these approaches with such students. (Received August 12, 2013)

1096-B5-177 **Girija S Nair-Hart*** (girija.nair-hart@uc.edu), Girija Nair-Hart, 4200 Clermont College Drive, Batavia, OH 45103. *Beyond the Letter Grade: Teaching and Learning in Mathematics Classrooms.*

As educators we provide a syllabus outlining the course's prerequisites, expectations and how learning will be assessed through quizzes and examinations. Students who provide correct answers within the allowed time get good grades and are labeled as good in mathematics and students who do not perform as well get lower grades. However, the diminished performance of students with lower grades can often be attributed to limitations unrelated to the breadth of their mathematical knowledge. Students that do not excel on quizzes and exams can have a good grasp of the big picture with many details, but are simply unable to provide the finished output with the time allowed. Alternatively, some high-achievers are excellent time managers who perform well without a detailed, coherent picture of the subject matter? During this presentation I will discuss my first-hand experience during my research on students' conceptual knowledge of the limit concept with 19 calculus 2 students at a major University. The first part of my research helped me identify the limitations of traditional instructional and assessment practices. The second part of my research helped me identify successful instructive practices that could foster increased student learning and student performance (Received August 13, 2013)

1096-B5-230 **Jennifer Franko Vasquez*** (jennifer.vasquez@scranton.edu), Mathematics Department, Scranton, PA 18510. *Using Exam Wrappers in a Calculus Class.* Preliminary report.

Exam Wrappers are a short survey given after each exam which encourage students to reflect upon their learning. They force the student to examine his or her performance in the context of their preparation and perception of understanding of the material. They can help students identify effective learning strategies and techniques. In this talk, I will discuss my experience using exam wrappers in Calculus I. (Received August 21, 2013)

1096-B5-240 **David C. Clark*** (dcclark@umn.edu). *Standards and outcomes and grades, oh my!*

Traditional points-based grading systems can leave both instructors and students with a muddled understanding of student performance. Most importantly, point totals don't indicate mastery of the key learning objectives in a class. Most instructors have experience with students who manage a passing grade without mastering important ideas, while others work hard but barely pass. In addition, it is difficult to assign meaningful point values to student participation in an active learning classroom.

Standards-based grading helps to address each of these issues: Students earn grades by demonstrating mastery of a set of standards, which correspond to the major learning objectives of the class. A major advantage of this system is that it shows everyone involved what objectives a student has achieved, and what requires more work.

We will describe the advantages and disadvantages of standards-based grading, reflect on its use in a senior-level coding theory class, and give suggestions and describe pitfalls for instructors considering its use. (Received August 22, 2013)

1096-B5-282 **Jonathan K. Hodge*** (hodgejo@gvsu.edu). *A Mastery-Based Assessment Scheme for Upper-Division Mathematics Courses.* Preliminary report.

In this talk, I will describe a mastery-based grading scheme that I have used for several years in upper-division mathematics courses including abstract algebra, discrete mathematics, and advanced calculus. Rather than receiving numerical grades on tests and other assessments, students are awarded improvable marks that indicate their level of mastery of course objectives. Through formative feedback and multiple opportunities to demonstrate mastery, students are encouraged to learn from their mistakes and strive to improve their understanding of course concepts. In addition to discussing practical details, I will also reflect on some of the benefits and challenges of using a mastery-based system, including responses from students. (Received August 26, 2013)

1096-B5-335 **Reva Kasman*** (rkasman@salemstate.edu), Salem, MA 01970. *Assessment Using Typed Feedback and Portfolios in a Course for Middle School Teachers.* Preliminary report.

The course "Patterns, Relations and Algebra for Middle School Teachers" covers a variety of algebraic topics and techniques, but it also focuses on developing important skills that are difficult to assess through routine exercises and traditional grading. Students are expected to strategize through unfamiliar problems, make conjectures, analyze solutions, use multiple approaches to problems, and communicate their ideas articulately to others. To foster and assess the acquisition of these skills, I use a twofold approach. Students complete frequent short assignments for which I provide individual typed feedback, making no markings on their actual submissions. Subsequently, students create portfolios in which they revisit their original problem sets, reflect on progress, and improve on solutions in response to the earlier feedback. (Received August 28, 2013)

1096-B5-381 **Victor U. Odafe*** (vodafe@bgsu.edu), 320 C West Building, One University Drive, Huron, OH 44839. *Assessing Students' Learning: The Interview Approach.*

Interviewing students enables us to gain insight into students' conceptual knowledge and reasoning as they engage in mathematical problem solving. Presenter will discuss practical issues of implementation as well as the level of students' success with the interview approach. A scoring rubric for this assessment approach will be shared. (Received August 31, 2013)

1096-B5-397 **Christopher Oehrlein*** (coehrlein@occc.edu), Oklahoma City, OK. *Assessment Across the Spectrum in Courses for Pre-Professional Majors with Calculus I Prerequisites.*

Pre-Med, Engineering and Business majors are required to take some form of calculus sequence. Many of them do not understand why that requirement exists, and some students are openly hostile about it. Instructors in a second course expecting mastery of Calculus I without spending any time revisiting the topics only heighten student anxiety and frustration. There is a gap between instructor and student expectations over what a Calculus I prerequisite means. An effect of this gap can be intensification of student hostility toward instructors, especially when they are assessed using only traditional homework and exams over what are perceived as complicated and irrelevant symbolic and computational procedures. Many problems in courses with Calculus I prerequisites can be addressed by diversifying assessment procedures. Low-stakes assessments like guided reading and applet play, multiple-attempt homework mastery (including relevant review) and classwork debriefing set the stage and provide confidence for improved performance on higher-stakes exams and projects. Homework involving writing without symbols moves students beyond unmotivated memorization of too many procedures towards memorization of basic formulas and concepts that make sense in the context of an entire course. (Received September 01, 2013)

1096-B5-548 **Kien H Lim*** (kienlim@utep.edu), 100 Colina Alta Dr, El Paso, TX 79912. *Using Multiple-Choice Items to Assess Students Individually and Immediate Feedback Assessment Technique (IF-AT) to Foster Student Engagement and Small Group Discussion.* Preliminary report.

This presentation provides examples on how multiple-choice questions (MCQs) can be designed to assess students' comprehension of assigned reading of math texts, conceptual understanding, and/or ability to apply their knowledge. How these MCQs can foster higher-order thinking and mathematical reasoning will be illustrated. Implementation strategies will be shared. For example, students have three boxes to enter their answer(s) for each MCQ; they can enter the same choice (e.g. C-C-C) if they are confident of a particular answer or a combination of choices (e.g. C-B-E) if they are uncertain. After working on the MCQs individually, the same MCQs can be used to engage students to work in a small group, communicate and exchange ideas, evaluate each others' reasoning, address discrepant ideas, and gain consensus. An IF-AT form, with a thin opaque film covering the correct answers, provides students with immediate feedback as to whether their answer choice is correct. Students can keep scratching until they find the star which denotes the correct answer. This presentation offers practical tips on how to design engaging MCQs and how to use MCQs to engage students and foster mathematical thinking and learning. These MCQs are used in a math course for pre-service EC-8 teachers. (Received September 05, 2013)

1096-B5-609 **Joel Louwsma*** (jlouwsma@ou.edu), Department of Mathematics, The University of Oklahoma, Norman, OK 73019. *Assessing student learning through writing assignments.*

Mathematical writing assignments require students to communicate their reasoning to an extent not normally expected on traditional homework assignments and exams. They therefore give greater insight into student thought processes and are especially useful as measures of deeper understanding. In this talk, I will describe how I have used writing assignments in my differential equations courses and discuss some of the advantages and challenges of using writing assignments as a method of student assessment. (Received September 07, 2013)

1096-B5-822 **Bonnie Gold*** (bgold@monmouth.edu). *Assessing Applications in Second-Semester Calculus.* Preliminary report.

Normally one chapter of calculus 2 is devoted to applications of the integral. I have never liked assessing this via traditional examination questions, because it requires students to memorize a range of formulas from assorted partner disciplines. As an alternative, I have students, in groups of two or three, choose which application they will present, and assign and grade homework from the class. The class then votes on which two applications will appear on the examination. I will discuss assorted features of the applications project, including my grading rubric, that make it work well. (Received September 10, 2013)

1096-B5-845 **Kristi Meyer*** (kristi.meyer@wlc.edu), 8800 W. Bluemound Rd., Milwaukee, WI 53226. *Tell Me What You Know: Oral Exams in the Undergraduate Mathematics Classroom.*

In many mathematics classes, a traditional cumulative written final exam makes up a large portion of a student's grade. The score on the final exam can often mean the difference between success and failure in the course. Such a high-stakes exam, however, may not always be the best way to accurately assess student learning, especially in upper-level mathematics classes. In this talk, I will discuss an alternative final exam approach – the oral final exam – which I have implemented in several of my mathematics classes. I will highlight the creation, evolution, and implementation of the oral exam and compare student performance on oral exams with performance on traditional written final exams. I will also discuss several practical issues and challenges associated with the use of an oral final exam. (Received September 10, 2013)

1096-B5-1109 **Hortensia Soto-Johnson*** (hortensia.soto@unco.edu), UNC School of Mathematical Sciences, Ross Hall 2240C, Greeley, CO 80639. *Perceptuo-motor Activities as Assessment.*

One of the premises of embodied cognition is that one develops perceptions and conceptions via bodily actions. Furthermore, it is believed that these bodily actions can reflect one's perceptions of a concept. As such, perceptuo-motor activities may serve as a means for assessing students' understanding of mathematical concepts. In this presentation, I will share perceptuo-motor activities to assess students' understanding of geometric transformations. While such activities can be time-consuming, they allow instructors to assess students understanding via their actions. Plus, they are fun. (Received September 13, 2013)

1096-B5-1147 **Eric Gaze*** (egaze@bowdoin.edu), Brunswick, ME 04011. *Projects in a Quantitative Reasoning Course.*

This talk will present several examples of projects from a Quantitative Reasoning (QR) course. QR by definition is more than just the development of quantitative skills, but involves a disposition to engage quantitative information in a reflective and systematic way to be used in decision making. To develop this habit of mind we need to create assessment items which are "ill-posed" and open ended. These problems will usually not have an exact solution but focus on generating insights which inform decision making and support valid inferences. The projects discussed will involve working with real world datasets, spreadsheets and writing with numbers. Validity issues will be discussed through the use of a traditional QR assessment instrument that has been developed as part of a NSF TUES project. (Received September 13, 2013)

1096-B5-1171 **Victor I Piercey*** (piercev1@ferris.edu), Ferris State University, Department of Mathematics, 820 Campus Drive ASC 2021, Big Rapids, MI 49307. *Assessing Projects and Inquiry-Based Activities in Quantitative Reasoning.* Preliminary report.

In this talk, I will discuss how I assessed student learning in two different quantitative reasoning courses. One course was project-based, while the other was an inquiry-based course specifically for business students. In addition to describing the assessment techniques, I will also evaluate whether I thought that this assessment was effective, and if there is anything I am going to change. (Received September 13, 2013)

1096-B5-1388 **Nina Juliana White*** (whitenj@umich.edu). *Holistic, diagnostic grading rubric for student presentations in an IBL geometry course.* Preliminary report.

In an inquiry-based learning (IBL) geometry course for future teachers, I wanted to assess students on their in-class presentations in a diagnostic way; that is, I wanted to give students a grade as well as give them feedback on how to improve. Further, in order to encourage holistic improvement, I wanted to stay away from a "points" system of grading that implied, for example, that a student achieved "60% of a presentation." To meet this goal I developed a checkmark grading rubric that assessed students' success in several aspects of their presentations: Exposition, Clarity, Correctness, Justification, and Responsiveness to audience concerns. In this talk I'll discuss

- the rubric,
- the nuts and bolts of using the rubric (including how I selected students to present, how I used the rubric in real time, how I got feedback to the students, how I augmented the feedback with in-class discussion, how I assigned final grades, etc.),
- and, most importantly, how student presentations evolved during the semester in reaction to the feedback.

(Received September 15, 2013)

1096-B5-1451 **Polina Sabinin*** (polina.sabinin@bridgew.edu), Department of Mathematics, Bridgewater State University, 131 Summer Street, Bridgewater, MA 02325. *Aligning Assessments to Problem-based Mathematics Classrooms: Three Examples of Assessment Tools.*

Students benefit from opportunities to experience mathematical inquiry and problem solving which support deep understanding of central mathematical concepts. So, professors have lots to do: develop a careful progression of problems, questions, and experiences to engage students' inquiry; think of ways to support students' perseverance through challenging problems; and provide opportunities for students to communicate their thinking verbally and in writing. In my courses, much of this happens in small groups and involves collaboration and communication between students. Here is the challenge: for all classroom experiences, there must be a valid assessment which aligns not only with WHAT was learned but also HOW it was learned. In this session, I will share three assessment items that I use in my courses for future elementary teachers: Classroom Synthesis and Analysis (CSA); group exams; and peer participation evaluation. I will provide attendees with helpful resources for easy adoption in their classrooms. (Received September 15, 2013)

1096-B5-1457 **Edwin O'Shea*** (osheaem@jmu.edu), Dept. of Mathematics & Statistics, James Madison University, MSC 1911, Harrisonburg, VA 22807. *The Utility and Practice of the Daily Quiz.*

Even in this modern era where homework solutions can be found, bought and sold on the internet, the process by which a student engages with mathematics through regular homework is still thought to be a crucial axis in the student's success in a course. In this context, we argue that homework should still be submitted by the student but instead of a thick ream of dog-eared paper it can instead take the form of a very short daily quiz where the questions are taken directly from the assigned homework.

What distinguishes our daily quiz from being only an assessment tool is that it acts as a pedagogical gun on the wall. Typical weekly quizzes last 20 minutes with the remaining class time being breathlessly spent on introducing a new section. With the five minute daily quiz, questions can be chosen every day so that the content of the short quiz feeds directly into the topic to be discussed that day. In short, class meetings with a daily quiz obey Chekhov's principle: if there is a gun on the wall it must go off.

Lastly, the daily quiz also keeps the student honest and invested in their homework. Practical tips for effective implementation and timely grading of said quizzes will be provided. (Received September 15, 2013)

1096-B5-1622 **Yun Lu*** (lu@kutztown.edu), Mathematics Department, Kutztown University of PA, Kutztown, PA 19530. *Students Presentation in Calculus I.*

This talk describes how the presenter applies the alternative assessment of the students presentation to promote the deeper learning in her calculus I class. The presenter will focus on practical issues of implementation and discuss the level of success of this assessment in the classroom. The presenter will also share the students' feedback if time allows. (Received September 16, 2013)

1096-B5-1648 **Emma Smith Zbarsky*** (smithzbarskye@wit.edu). *Using oral examinations to improve student learning.*

Over the past two years I have begun using individualized oral examinations near the end of the class as a significant component of student assessment in my courses. Such exams allow both the student and myself a chance to observe each student's competence with the material. For that last year, the oral exam has been an optional retake covering the same material as one of the written exams earlier in the course. Nearly every student opts to take the oral exam. Students generally show significant improvement when given the opportunity to show off the results of their study in person with the professor. Students have also commented that they appreciated the format of an oral examination as a study aide before the final exam. I shall present my data on student outcomes and student feedback regarding the oral examinations. (Received September 16, 2013)

1096-B5-1778 **M Leigh Lunsford*** (lunsfordml@longwood.edu), 808 High Street, Farmville, VA 23901, and **Phillip L Poplin**. *The Scarlet Letter: How We Repented and Came to Value Purposeful Assessment.*

Mention the word "assessment" in a crowd of educators and you will hear a collective groan. We were once among those groaners. However, through a multi-year program of assessment and intervention, we have come to the conclusion that assessment can actually be useful. In this talk we will discuss how we have used assessment with the purpose of improving student success in non-calculus introductory statistics at Longwood University. Following an action research model we used assessment results from our first study to inform the implementation of an early intervention program in our second, follow-on, study. In our first study, conducted during the 2006-2008 academic years we found, among other results, that students who have poor basic mathematics skills are less likely to succeed in the course. Those results lead to our second study, started in 2011 and recently completed, in which we implemented an early intervention program (required tutoring) for these students. We will discuss the results from both studies as well as how we believe assessment can actually be used for a purpose and not be the bane of our existence. (Received September 17, 2013)

1096-B5-2151 **Erin E. Bancroft*** (eebancroft@gcc.edu). *Oral Exams— They're Not Just for Dentists.*

A primary goal of assessment is to obtain a comprehensive picture of a student's understanding and mastery of the material. Traditional assessment methods give a one-sided view, particularly in classes where presentations and group work are more common than lectures. Incorporating oral exams can provide a more complete picture by allowing the assessor to tailor the assessment to the individual student on the spot. Oral exams are also well-suited to assessing the mathematical thinking and reasoning skills that we desire our students to acquire.

In the talk, I will expand on the rationale behind my use of oral exams for both introductory and advanced major classes. On a practical level, I will discuss my implementation process and the advantages and disadvantages to this assessment method. I will also share students' responses and reactions both before and after they underwent the assessment. (Received September 17, 2013)

1096-B5-2155 **Eric D. Bancroft*** (edbancroft@gcc.edu), Grove City College, 100 Campus Dr, Box 3121, Grove City, PA 16127. *Reading vs. 'Rithmatic.*

Is collecting homework the best way to assess students' understanding of the material? How much accountability do students need in order for them to complete the homework before an exam? Would students' performance change if they were asked to read the section before the lecture and homework was not collected? In this talk I will share my experiences with supplementing and replacing traditional collected homework with reading assignments. (Received September 17, 2013)

1096-B5-2304 **Amy T DeCelles*** (adecelles@stthomas.edu). *Blending Evaluative and Formative Assessment.*

After giving students thirty minutes to work on a half-exam-length quiz individually, I asked them to put their pencils down and reflect on how they thought they did. I then surprised the students by encouraging them to discuss the problems together and improve their responses. Quite a lively discussion ensued. In the last ten minutes of class I allowed them to ask questions of me and continue to improve their responses. Administering a quiz in this way provides an opportunity for self-evaluation, peer learning, and instructor feedback in one assessment. (Received September 17, 2013)

1096-B5-2442 **Clark Wells*** (wellsc@gvsu.edu), Dept. of Mathematics, Grand Valley State University, 1 Campus Dr., Allendale, MI 49426. *Moving Beyond Ritual.*

Whether it is becoming more of a problem or whether I am only now realizing what I think the problem is, a troubling trait that I see in many mathematics majors, even in upper division courses, is what Harel, et al., describe as a ritualistic understanding of proofs. This has led me to adopt in all of my courses for majors the course objective of students being able to observe, generalize, conjecture, and refine their conjectures. The problem with this objective is that learning these skills requires substantial formative feedback, but with traditional assessment methods, formative feedback is either not graded, and thus not valued by students, or by its nature punitive.

In their 2012 article, Brilleslyper, et al., discuss their implementation of a grading system that does not use points. Among the advantages they ascribe to their system are increased focus of students on learning rather than grades, increase in students' intrinsic motivation, and alignment of learning experiences with course objectives.

In this talk I will discuss my implementation of a similar assessment program for our introduction to proofs class, with special emphasis on its effectiveness in helping students develop the skill of conjecturing. (Received September 17, 2013)

1096-B5-2460 **Christina E Therkelsen*** (christina.therkelsen@uc.edu). *Student Presentations in a Large-Section Calculus Course.* Preliminary report.

Traditional calculus courses are often lecture-based, sometimes with brief periods spent working on problems whose solutions are ultimately presented by the instructor. In this setting it can be easy for students to become disengaged in the course and take little ownership over their learning experience. In redesigning a large-section calculus course for business students, we scheduled time for weekly individual student presentations and group work on more challenging problems, the results of which are also presented by students. These students have responded with energy and determination to solve challenging problems beyond previous expectations. In this talk, I will give a description of this alternative type of assessment via the rubric we used to grade presentations, along with sample problems and student feedback. (Received September 17, 2013)

1096-B5-2467 **Dan Callon*** (dcallon@franklincollege.edu), 101 Branigin Boulevard, Franklin, IN 46131. *Student-Driven Assessment.* Preliminary report.

Good mathematics educators know that not all students learn the same way. Yet we typically apply the same assessment structure to all students.

Besides assessing content mastery, we usually also have certain skills or dispositions we would like the students to acquire. Yet the student who actually acquires that skill but not until near the end of the course may have a poor grade because of low scores on early assessments.

I have used a two-pronged approach in sophomore-level courses. As part of assessment in multivariable calculus I have used periodic learning reports in which students document their content mastery in whatever way they can. These reports also ask for evidence of preparation for and engagement in class and of contributions to others' learning. Each report is evaluated using a rubric, and a final score assigned based on overall semester accomplishments but also whether the trend is upward or downward.

In linear algebra each student earns part of the final grade by negotiating a personal learning plan with me. That plan is designed to address the areas in which that student is weakest.

I will discuss my experiences and the advantages and disadvantages I have encountered. (Received September 17, 2013)

1096-B5-2486 **Elizabeth Theta Brown*** (brownet@jmu.edu), Department of Mathematics and Statistics, MSC 1911, JMU, Harrisonburg, VA 22807. *The Old is New Again: Oral Assessment in Undergraduate Mathematics.*

Oral examination is, after a long hiatus, relevant again in undergraduate mathematics assessment. New interest in active learning in the classroom, and new approaches to fostering deep learning, indicate that it is time to rethink current standard, static, methods of determining what students learn. At the same time, plagiarism pressure from the internet has undermined the integrity of the graded problem set, a previous generation's tool for evaluating students' deep mathematical thinking.

This talk will outline strategies, successes, and challenges of using oral examination and oral communication to assess undergraduate mathematical performance. We will discuss different instantiations of this notion of verbal communication as a central method of assessment that have been used in math courses from introductory to senior levels. (Received September 17, 2013)

1096-B5-2570 **Annela R Kelly*** (a3kelly@bridgew.edu). *Learner-centered Assessment in Calculus.* Preliminary report.

The talk will present a version of self-assessment where students are active participants. I developed worksheets with self-assessment for my Calculus II and III class. The students will rank their knowledge in several categories as an evaluation of their skills. To summarize, the students work on self-reflection and goals. (Received September 17, 2013)

1096-B5-2648 **Thomas R. Hagedorn*** (hagedorn@tcnj.edu). *Assessing a Capstone Course.*

In the 2012-13 academic year, our Department of Mathematics and Statistics introduced capstone courses for its graduating seniors. Three different capstone courses in Mathematics, Applied Mathematics, and Statistics were offered. Students worked on projects, both in groups and individually, based on a common theme for the course. The final projects were presented in a poster session for the department faculty and student peers based upon the MAA's Undergraduate Research Poster Session. No tests or quizzes were given. This talk will discuss how students were assessed, and changes we have made for doing assessment for this coming Spring. (Received September 17, 2013)

1096-B5-2678 **Brian Katz*** (briankatz@augustana.edu), 639 39th St, Rock Island, IL 61201. *Collaborative Assessments.*

My courses emphasize active learning experiences for the students, and consequently these experiences tend to be collaborative. My students are rarely asked to work completely alone, nor do I expect that they would do so very often after leaving my course. As a result, I have experimented with assessments that allow collaboration and are more in line with their practice experiences. I plan to talk about a pair of connected assessments: an open-class take home exam and a collaboratively student-written reference textbook, both from Calculus I. (Received September 17, 2013)

Assessment of Proof Writing Throughout the Mathematics Major

1096-C1-569 **Sarah K. Bleiler*** (sarah.bleiler@mtsu.edu), MTSU Box 34, Murfreesboro, TN 37132, and **Justin D. Boyle**, **Yi-Yin Ko** and **Sean P. Yee**. *Communal Assessment of Proof: Undergraduates' Development of Proof-Writing Criteria.* Preliminary report.

Undergraduate students often view writing mathematical proofs as a specific procedure that is replicable, and believe that the mathematics instructor is the one who holds the authority to judge the validity of their mathematical arguments as final product. In the mathematics community of practice more generally, mathematicians negotiate the validity of presented arguments. Our perspective is that students should engage in mathematical proof as a negotiating and sense making process, which more closely aligns with the practice of mathematicians. To support students' active involvement in proving, we designed and implemented an instructional sequence wherein students constructed arguments, validated one another's arguments, and composed a list of proof-writing criteria based on their validations. These criteria served as a framework for undergraduates to revise and resubmit their original arguments. In this way, what "counts" as mathematical proof was determined by the classroom community as a whole, rather than solely by the instructor. We discuss the results of this instructional sequence, implemented in two content courses and two methods courses at four different institutions, and provide implications for supporting students as they actively consider what counts as 'proof.' (Received September 06, 2013)

1096-C1-707 **James E Hamblin*** (jehamb@ship.edu), 1871 Old Main Drive, Shippensburg University, Shippensburg, PA 17013. *Using Common Final Questions to Assess Proof.*

At Shippensburg University, we use a series of common final exam questions to measure the degree to which our students have mastered the idea of proof. We not only have students write simple proofs, but we also ask them to provide counterexamples; this is a fundamental part of understand the idea behind proofs and why we need them. We also ask the same question across multiple courses where applicable. In this talk, I will give the details of how our system works, as well as provide data for how well our students perform. (Received September 09, 2013)

1096-C1-1787 **Robert C. Moore*** (moorer@andrews.edu), Department of Mathematics, Andrews University, Berrien Springs, MI 49104. *Mathematics Professors' Evaluation of Students' Proofs.*

This study examined mathematicians' beliefs and practices in evaluating students' proofs and teaching students to write proofs. Four mathematicians were interviewed in the fall of 2012. In the first part of the interview, they evaluated five or six proofs of elementary theorems written by students in a discrete mathematics or geometry course. The professors talked aloud as they wrote marks and comments on the proofs and assigned a score out of 10 points to each proof. In the second part of the interview, they responded to questions about the characteristics of a well-written proof and how they communicate these characteristics to students. The results indicated that these mathematicians agreed that the most important characteristics of a well-written proof are (a) correct logic and (b) clarity. Although these mathematicians differed in the attention they gave to layout, grammar, punctuation, and mathematical notation, they agreed in giving these characteristics relatively little weight in the overall score. They said that they communicate the characteristics of a well-written proof to students primarily by (a) modeling good proof writing in class and (b) writing comments on students' papers. (Received September 16, 2013)

1096-C1-2623 **Sarah V Cook*** (sarah.cook@washburn.edu), KS. *Using a Rubric to Assess Development of Proof-Writing.* Preliminary report.

In my proof classes at Washburn University, I use a rubric to assess proof-writing. The rubric is divided into two components, namely logic and writing. The rubric is used to grade proofs on both homework and exams. In my introductory proof course, specific proofs on the final exam are marked as assessment problems. Proofs similar to these final exam problems are given as a review assignment in my upper-level proof course and are also graded with the rubric. In this session, we will present the rubric and discuss how it was developed. We will also compare the scores of proofs in the introductory course with the scores on the review assignment in the upper-level course. (Received September 17, 2013)

At the Intersection of Mathematics and the Arts

1096-C5-136 **Shelley Lynn Rasmussen***, Mathematics Department, Olney 428T, Lowell, MA 01854. *Colorings of Plane Patterns Defined by Sequences ad Arrays, With Applications to Weaving.* Preliminary report.

This work describes schemes for coloring an $m \times n$ grid in two or more colors. Such a grid is based on the "product" of two q-ary sequences, one of length m and the other of length n, each built from an alphabet $\mathbb{A}$ containing q distinct symbols and a $q \times q$ product matrix that defines the product of two elements a_i and a_j of $\mathbb{A}$. With this product matrix and a color set containing up to q^2 colors, we define the $m \times n$ product of two such q-ary sequences, along with its associated $m \times n$ colored grid. Considered in detail is the special case when the product matrix is a one-step right circulant latin square and the number of colors is from 2 to q. These ideas are then extended to a systematic procedure for creating patterns within patterns (nested or hierarchical designs). Because a traditional weaving draft or drawdown is a rectangular grid of black and white squares that defines a fabric structure, these results can be applied to textile design, allowing for construction of hierarchical patterns not previously described in the weaving literature. (Received August 07, 2013)

1096-C5-200 **Shirley Basfield Dunlap*** (shirley.dunlap@morgan.edu), Morgan State University, Department of Fine and Performing Arts, 1700 E. Cold Spring Lane, Baltimore, MD 21251, **Asamoah Nkwanta** (asamoah.nkwanta@morgan.edu), Morgan State University, Department of Mathematics, 1700 E. Cold Spring Lane, Baltimore, MD 21251, and **Jalecia King**, **Brian Jamal Marshall**, **Sudani Rose**, **Eirin Stevenson** and **Keisheena Waldon**. *Bridging the Gap: Linking HIV/AIDS and Random Matrices to Theatre Arts.* Preliminary report.

The purpose of this talk is to discuss the integration of STEM and Theatre Arts. STEM research topics from random matrix theory and HIV/AIDS will be linked to theatre resulting in the creation of an integrated script. This transdisciplinary research study illustrates the important role mathematics has within a performance concerning a potential development of an HIV vaccine. The script's purpose is to educate Baltimore City's youth and young adults about HIV/AIDS. The overall objective of this project is to use theatre to increase HIV/AIDS awareness and prevention and to help popularize mathematics. (Received August 15, 2013)

1096-C5-226 **Michael Huber***, huber@muhlenberg.edu. *A Mathematical Perspective of Rome's Twin Churches.* Preliminary report.

The Piazza del Popolo is one of the larger and more scenic locations in Rome, and it is situated only a few hundred meters northwest of the famous Spanish Steps. On the south side of this elliptically-shaped piazza lie two churches, Santa Maria di Montesanto and Santa Maria dei Miracoli, known as the Twin Churches. The churches were designed to be identical in the 17th century, as seen from the northern side of the square. This identical appearance is due to perspective, not to symmetry. The churches in fact have totally different ground plans and dome structures, yet they appear identical, thanks to Bernini. This paper describes an approach for instructors of introductory symmetry and shape courses which applies to actual buildings, in calculating the perspectives and volumes of structures which have elliptical or circular shapes. Practical applications of online 3-dimensional rendering is employed. (Received August 21, 2013)

1096-C5-229 **Daniel M. Look*** (dlook@stlawu.edu), SLU Dept of Mathematics, 23 Romoda Drive, Canton, NY 13617. *It Came from the Fourth Dimension!: Visualizing Higher Dimensions through the Art of Comic Books.*

Comic books are rarely used as mathematical resources. However, artistically, comic books have an advantage over other visual media in terms of conveying higher dimensional spaces. We will focus on an issue of Steven Bissette and Alan Moore's *1963 Comics* which features a battle between the character Hypernaut and an invader from "The Fourth Dimension" to explore how the artistic space created by the panels of a comic book lend themselves to portraying higher dimensions. Further, we will see that this particular issue could serve as a companion to Edwin Abbot's *Flatland* in a course discussing higher spatial dimensions. (Received August 21, 2013)

1096-C5-303 **Neal Brand*** (neal@unt.edu), University of North Texas, Mathematics Department, 1155 Union Circle #311430, Denton, TX 76210. *Spindle Design.*

Before the spinning wheel, yarn and thread were made using spindles. There has been a recent renewed interest in spinning using hand make spindles. Spinners wish to have spindles that are both functional and attractive. We will discuss a project that was given to a first semester calculus class that required students to design a Tibetan style support spindle that could be used to spin yarn. The project required students to use Riemann sums to derive the formula for the moment of inertia for a solid of revolution and apply their formula to design an attractive spindle with the right moment of inertial. (Received August 27, 2013)

1096-C5-330 **Hossein Behforooz*** (hbehforooz@utica.edu), 1600 Burrstone Road, Utica College, Utica, NY 13502. *Interesting Artworks on Magic Squares.*

This talk includes two parts. In part one, a collection of magic squares expressed in visual art forms will be presented. In part two, we will discuss on a new subject "Balance Points of Weighted Magic Squares, Stars and Circles". Here we are totally changing the concept of the flat magic squares from table of numbers to three dimensional object in space. We really see them and feel them as balanced hanging weights, columns, or wind charms. One of these weighted magic squares will be part of the Mathematical Art Exhibition Section during the Joint Mathematics Meeting 2014. (Received August 28, 2013)

1096-C5-343 **Neil R. Nicholson*** (nrnicholson@noctrl.edu) and **Jonathon Kirk** (jkirk@noctrl.edu). *Euclidean Rhythms and Tangles.* Preliminary report.

Recently there has been growing interest in music theory to develop and study advanced geometrical models for the analysis of both pitch space and isomorphic rhythmic structures. Toussaint recently discovered ways of generating several well-known cyclical rhythms that have defined the rhythmic structure of many traditional musics of West Africa, Cuba, Brazil and beyond. By generating rhythms from a binary format described by Bjorklund using the Euclidean algorithm, Toussaint has described a combinatorial classification for these rhythms by representing their unique interval vectors on a two-dimensional circular lattice. This visual representation can be useful for both the analysis and algorithmic generation of cyclical rhythms. To encourage further research and to find rhythmic/visual applications within algorithmic music composition, the authors find a relationship between the generative process of Euclidean rhythms and their connection to geometrical representations unique to tangle theory. We will demonstrate both directions of the correspondence by first generating the representative rational tangle associated with the African Bembé rhythm and then derive other various rhythms from similar yet different rational tangles. (Received August 29, 2013)

1096-C5-413 **Reza Sarhangi*** (rsarhangi@towson.edu), Department of Mathematics, Towson University, Towson, MD 21252. *Interlocking Polygonal Tiling of Some Special Class of Star Polygons.*

This presentation is about methods for tiling the surfaces of some star polygons that are constructed using a (10, 3) star polygon. Based on this star polygon we are able to construct two stars that are used in many traditional Persian tiling: a five-pointed and a ten-pointed star. For convenience we will call them a pentagram (that is different from a (5, 2) star polygon, which is usually called a pentagram) and a decagram. A pentagram can be constructed using the intersections of segments that constitute a (10, 3) star polygon. It can also be generated by the rotation of a 72 degrees rhombus rotating around the vertex of the 72 degrees angle. A decagram can be constructed using a (10, 3) star polygon. It also can be created through the rotation of two concentric, congruent regular pentagons with a radial distance of 36 degrees from each other's central angles. We study the creations of decorative pentagrams and decagrams that are covered by different sets of motifs (polyhedral tessellations) with the conditions that: (a) the tessellations have 5 or 10-fold rotational symmetry, and (b) the vertices of the main frames of the tessellations are located at the center of the small decagram motifs that constitute the tiling. (Received September 03, 2013)

1096-C5-434 **Anne M Burns*** (aburns@liu.edu), Mathematics Department, Long Island University, Brookville, NY 11548. *Fractal Trees Inspired by Iterating Rational Functions.* Preliminary report.

A picture is worth many pages of computations. This talk will show one way in which color can be used to visualize structure in a complex mathematical system. The tree-like structures that become evident from the pictures can be designed geometrically; by changing parameters an infinite variety of fractal trees and tree-like designs can be constructed. (Received September 03, 2013)

1096-C5-467 **Susan McBurney***, 211 Rugeley Road, Western Springs, IL 60558. *Finding the Way with Mathematics.*

Problem solving in one form or another has always been an integral part of man's existence, as has a desire to find one's way in the world. Systematic observation, documentation (even as rudimentary as marks inscribed on a bone) and logical conclusions were employed by the ancients long ago to understand the natural world and eventually lead the way to exploring the unknown. This presentation will trace the path of the mathematical methods used from the first astronomical observations through the development of more formal systems, to the computer revolution and on to today's exploration. Technical advances often brought new means for artistic expression as well, so we will also examine some of the beautiful graphics and ingenious navigational instruments and tools that emerged alongside the pivotal mathematical developments. (Received September 04, 2013)

1096-C5-558 **Emily H. Sprague*** (esprague@edinboro.edu), Mathematics and Computer Science, Edinboro University of Pennsylvania, Edinboro, PA 16444. *Giving freshmen a taste of abstract mathematics through ancient and modern concepts in music theory.*

In this talk we outline the development of mathematical awareness by students in my First Year Experience Seminar in the Mathematics of Musical Consonance. The seminar satisfies a general education mathematics requirement and is open to interested students who often have very little formal training in music theory.

The course makes use of the musical elements of diatonic tonality and familiar dance rhythms to touch upon several facets of mathematics. The course explores applications of arithmetic, discovers the inadequacy of limiting ourselves to rational numbers, finds partitions of the scale into various "pitch-class-sets," characterizes these partitions by distinct readily recognized half step patterns. Techniques to measure melodic intervals are contrasted with measurement strategies for rhythms whereupon analogous characterizations of rhythm classes evolve. Finally, we explore the idea of an isomorphism between melody and rhythm.

The materials of the course have been derived from several sources. We use well-known sources that explain Pythagorean tuning and equal temperament, excerpts from Timothy A. Johnson's work explaining the music theory of John Clough, and from Godfried Toussaint's exhaustive exploration of rhythm. (Received September 11, 2013)

1096-C5-588 **Godfried T. Toussaint*** (gt42@nyu.edu), New York University Abu Dhabi, P.O. Box 129188, Abu Dhabi, United Arab Emirates. *Geometry, Visual Patterns, and Musical Rhythm: Problems at the Interface.* Preliminary report.

Visual patterns have a more obvious connection with geometry than musical rhythms. Nevertheless, periodic (cyclic) musical rhythms may be conveniently notated on a circle, and thus also render themselves open to geometric analyses [1]. In this paper some geometric properties of patterns, and measures of pattern complexity are analyzed, that contribute to the characterization of "good" visual and musical rhythmic patterns. Conversely, it is illustrated by means of examples, that the exploration of meaningful visual and auditory patterns uncovers interesting new problems in mathematics.

[1] Godfried T. Toussaint, The Geometry of Musical Rhythm, Chapman & Hall: CRC Press, January 22, 2013. (Received September 06, 2013)

1096-C5-730 **Saul Schleimer** (s.schleimer@warwick.ac.uk) and **Henry Segerman*** (segerman@math.okstate.edu). *Triple gear.*

A relatively common sight in graphic designs is a planar arrangement of three gears, all in contact. However, since neighboring gears must rotate in opposite directions, none of the gears can move. We give a non-planar, and non-frozen, arrangement of three linked gears, presented as a kinetic sculpture. (Received September 09, 2013)

1096-C5-844 **B Lynn Bodner*** (bodner@monmouth.edu), Mathematics Dept, Monmouth University, West Long Branch, NJ 07764. *Which Planar Crystallographic Groups May Be Found in Mamluk Geometric Ornamentation?*

In the region extending from Arabia to Southern Anatolia, elaborate geometric tilings and patterns still cover the walls and ceilings of extant monuments from the Mamluk period (1250 – 1517). These planar Islamic patterns may be classified as belonging to the various crystallographic ('wallpaper') groups based on the distance-preserving transformations or isometries of the plane (translations, rotations, reflections and glide-reflections) that they possess. Classifying the patterns found as ornamentation on these Mamluk monuments allows us to determine which symmetries were preferred and intuitively recognized as being "right" by the Mamluk culture. This paper will discuss and illustrate examples of the different 'wallpaper' groups represented in the Mamluk art of present day Egypt and Syria. (Received September 10, 2013)

1096-C5-848 **Douglas G. Burkholder*** (doug.burkholder@lr.edu), 625 7th Ave NE, Hickory, NC 28601. *Planar and Spherical Iterations of Borromean Rings.*

Borromean Rings are a simple yet interesting set of three rings intertwined so that if any one ring is cut and removed, then the other two rings separate into unlinked rings. We investigate various ways to iterate both the planar representation and the spherical representation of the Borromean Rings to obtain artistically interesting weavings which continue to retain the above property that the three rings are linked together and yet each pair of rings is unlinked. (Received September 10, 2013)

1096-C5-1016 **Irene Iaccarino*** (irene.iaccarino@hotmail.it), via Interna Marina 19, 88900 Crotone, Italy, and **Rosanna Iembo** (rosannaiembo@libero.it), via Federico Cozzolino 18, 84018 Scafati, Salerno, Italy. *Food for empathy in the School of Pythagoras and his wife Theano.*

Pythagoras was the founder of mathematics, astronomy, music and also medicine, many centuries before Hippocrates and he set up the naturopathic system of recovery. In Crotone (southern Italy), with his wife Theanò, the first great scientist of mankind, he founded the school of knowledge and values, "the" School of the ancient west. Pythagoras and Theanò taught rigour, essentiality, frugality, sobriety and coherence. They created a style of life based on vegetarianism, health, respect, love and pacifism. They preached not to decay the body with impure foods; but to feed on wheat and apples, and grapes of vineyards, tasty grasses, milk and honey fragrant with thyme because the land provides a great amount of pure foods which do not cause bloodshed nor death. So they urged a non-carnivorous diet, not only for physical, mental and spiritual wellbeing, not only for love of animals, but because they believed that violence towards the weakest lead inevitably to violence among human beings. "Never sacrifice animals to gods or hurt animals, but at all levels promote a culture of respect and protection." That was the first great school of pacifism in the west where also food played a role in creating empathy. (Received September 12, 2013)

1096-C5-1213 **Violeta Vasilevska*** (violeta.vasilevska@uvu.edu), 800 W. University Parkway, Orem, UT 84058. *Math, Art and GeoGebra.* Preliminary report.

In this presentation, a math-art project that was used at a regional STEM conference for junior-high female students will be described. Part of this project could be adapted to a college Geometry class. It connects math (in particular geometry), origami, exploration with GeoGebra software, and art. First, some simple origami folds will be shown and the math behind it will be discussed. These origami moves produce tangents to some curves. This construction will also be demonstrated with GeoGebra software, and then used to construct some interesting art pictures. (Received September 13, 2013)

1096-C5-1242 **Matt Lehman*** (matt.comicopia@gmail.com), 466 Commonwealth Av., #407, Boston, MA 02215. *Δ(rhythms)/Δt = ? What Base Are Rhythms In?*

We will explore the relationship between music and time, without considering subjective musical aesthetics. For our model, we need only two parameters, pitch (p) and time (t). To avoid a doubly infinite answer, we'll need to make them discrete and finite ($p, t \in \mathbb{N}$). Letting $p = 1$ gives us a simplified problem, counting rhythms. We then ask a concrete question: How many rhythms are possible in a 4/4 measure of music if the shortest unit of time is a sixteenth note? Letting r_t = the number of rhythms with t units of time (beats), we'll find r_{16} by solving the general case. ($r_{16} \gg 2^{16}$). This will reveal rhythms' rate of growth and base. From here we can generalize p. We can now determine the minimum t such that every living person gets a unique rhythm ($p = 1$) or song ($p > 1$). As p grows how does t decrease? Can we strike a reasonable balance between them? Knowledge of music theory is not necessary. (Received September 16, 2013)

1096-C5-1405 **Elizabeth Whiteley*** (whiteley.artist@gmail.com). *Applying an Historical Approach to Contemporary Pattern Design.*

Prior to the popularization of the 17 symmetry groups in the 1930's, designers of 2-D ornamental patterns used various geometric plans. This talk presents contemporary patterns which are the results of 2-D generators repeated on 3 plans: squares, rhombi, and parallelograms. Ways to disguise the repeat, as described by the British designer Lewis Foreman Day in the 19th century, will be discussed. (Received September 15, 2013)

1096-C5-1407 **Robert M Spann*** (bobspann@gmail.com). *Implementing Multiple Compositional and Color Constraints in Algorithmic Art.*

There are direct analogs between the compositional rules and color theory principles that artists use and the mathematical and statistical properties of images. For example, the compositional principle that an image be balanced horizontally and vertically is equivalent to stating that the first horizontal and vertical geometric moments (or center of mass) are zero. Similarly, the compositional principle that an image have a focal point can be represented by the restriction that the standard deviation of the pixel values is high at certain parts of the image. Such composition rules are often used to evaluate algorithmically generated images. Alternatively, one could start by specifying the compositional constraints one wants the image to satisfy. These composition constraints can be written as equations which the pixel values of the image must satisfy. I use optimization techniques to produce images that simultaneously satisfy several pre-specified compositional constraints. (Received September 17, 2013)

1096-C5-1416 **Michael Pilosov*** (mp16@geneseo.edu). *Animating Still Images.*

We present a means of developing digital image transformations that allow a still image to be turned into a short and visually pleasing animation. Rather than manually augmenting successive frames to create the illusion of motion, the method presented here requires only the input of a few parameters for each transformation. We developed a mathematical framework wherein we defined animations as sequences of still images, and "transformations" as composable functions on such sequences.

To implement this work, we have built a MATLAB library of composable functions that streamline the process of turning still images into novel animations. Examples include manipulation of contrast, intensity, and colors of pixels, as well as warps of contours, positions, and size of select regions. The transformations allow for easy animation of regions of interest, giving some semblance of life to still images by turning them into animated GIFS. (Received September 15, 2013)

1096-C5-1431 **Lina Wu*** (linawupaul@gmail.com), 529 West 42nd Street Apt. 5K, New York, NY 10036. *Incorporating art in mathematical teaching and assessment as image-based learning.*

The presenter will introduce the pedagogy that uses images, such as artwork as scaffolding materials, to facilitate students' learning for the advanced math courses at college-level. The presenter integrated art in Calculus teaching and Calculus assessment in the pilot 2013 summer course at the Borough of Manhattan Community College. First was to guide student in learning Calculus concepts by identifying certain artwork that correlate with Calculus. Second was to use artwork as a tool to assess students' application ability of Calculus skills in art diagram design. This pilot course was funded by the Rubin Museum of Art in New York City. Students were assigned to complete out-of class projects such as visiting art museums to discover math subjects through selected artwork, making presentations to interpret math concepts in terms of art-related contexts, and designing art diagrams by applying math skills. The advantage of using visual elements such as artwork in math teaching was to let student see that Calculus is everywhere even in art. The most impressive point was to improve students' ability of cognitive understanding through the image of artwork and to enhance students' ability of making use of math skills to generate artwork. (Received September 16, 2013)

1096-C5-1522 **Rita A. Capezzi*** (capezzir@canisius.edu), 2001 Main Street, Buffalo, NY 14208, and **L. Christine Kinsey** (kinsey@canisius.edu), 2001 Main Street, Buffalo, NY 14208. *Literary Mathematics and Mathematical Literature.*

When two faculty members from widely separated disciplines have the opportunity to team-teach an honors course, unexpected and exciting knowledge is discovered in the intersection. We come from the departments of English and mathematics, and neither of us had more than a rudimentary knowledge of the formal content of the other field. In planning the course, we read widely and agreed on a selection of writings, many drawn from members of the Oulipo literary movement but also stories by Borges, novels by Calvino and Robbe-Grillet, and a play by Stoppard. Some of the texts discussed mathematics explicitly, but in others mathematics is used as a structuring device. The students, drawn from the college-wide honors program, came from a wide variety of majors, including mathematics and English, but also biology, business, and philosophy. While students wrote excellent standard analyses of the course texts, their true knowledge came through in creative work, where they employed the textual constraints under discussion. Our students' work highlights best the playful structures we all enjoyed reading and discussing, and we will bring examples to share. (Received September 16, 2013)

1096-C5-1629 **Randall E Cone*** (conere10@vmi.edu), 439 Mallory Hall, Virginia Military Institute, Letcher Avenue, Lexington, VA 24450. *The Sound of Mathematics: Pythagorean Music and Beyond.*

Deep connections between sound, music, and mathematics have been established for (at least) the last few millennia. This paper proposes and examines inquiry-based learning activities within the context of the manifold relationships between mathematics, sound, and music from throughout the ages. To this end, the activities herein demonstrate how to simultaneously cultivate student interest in music as well as some aspects of technical mathematics. (Received September 16, 2013)

1096-C5-1781 **JoAnne Growney*** (wow@joannegrowney.com), 7981 Eastern Ave, #207, Silver Spring, MD 20910. *Extending the poetry of mathematics to non-mathematicians.*

Many of us know the words of Karl Weierstrass (1815-97) – "It is true that a mathematician, who is not somewhat of a poet, will never be a perfect mathematician." – and of Albert Einstein (1879-1955) – "Pure mathematics is, in its way, the poetry of logical ideas."

Those of us a bit fluent in both mathematics and poetry can compare and perhaps equate the rush of emotion, or the delight, or the "aha" of understanding derived from taking in a powerful and elegant proof with that from a powerful and elegant poem; such experiences prod us to agree with Weierstrass and Einstein. And non-mathematicians may, based on their experiences with poetry, accept mathematics as poetry by analogy – the elation gained from poetry gives them a model for that which is math-generated.

Mathematician and poet JoAnne Growney has engaged in a long and sometimes successful search for samples of mathematics that may seduce non-mathematicians into direct experiences of knowing mathematics-as-poetry. This presentation offers the results of that search. (Received September 16, 2013)

1096-C5-1802 **Susan Happersett*** (fibonaccisusan@yahoo.com), 344 Grove St # 10, Jersey City, NJ 07302. *Fibonacci Circle Curves.*

I have created a series of drawings using circles. The measurement of the areas of the circles corresponds to ratios of consecutive Fibonacci numbers. I made templates for the first eight circles and experimented. In the first attempt all circles were in a straight line. To make it more aesthetically interesting I broke up up the straight line connecting the center points into angled line segments. The angle I liked best was the Golden Angle. It is the smaller of the two angles formed by two radii that divide the circumference of a circle into two arcs so that the ratio of the measurement of the large arc to the small arc is equal to the ratio of the of the total circumference to the measurement of the larger arc.

With this drawing as a building block, I made a number of drawings on transparent paper and superimposed and shifted the images. I wanted the work to have a sense of movement. Using the line segments that connect the center points of adjacent circles as a guide, I dragged the template of the first circle, so that the center point stayed on the guideline. Then I drew multiple circles until the first circle was completely inside the second, sharing one circumference point. I repeated this with each of the circles. The finished product was an image with potential. (Received September 16, 2013)

1096-C5-1922 **Robert W Fathauer*** (tessellations@cox.net), 3913 E. Bronco Tr., Phoenix, AZ 85044. *Hyperbolic Fractal Tilings.*

We have previously described a variety of fractal tilings (f-tilings), in which tiles are adjacent to larger and smaller tiles that are similar. These f-tilings contain singular points and are of finite extent in the Euclidean plane, with

boundaries that are fractal curves. We report here on f-tilings in which the sum of the angles meeting at a vertex is greater than 360 degrees. These have been constructed in Euclidian 3-space using both Mathematica and paper models. In most of the hyperbolic f-tilings that have been examined, the prototile is an isosceles triangle in which the two sides of equal length are shorter than the third side. Second generation triangles are scaled such that their long edges match the two short edges of first generation tiles. The smaller tiles are deflected out of the plane of the adjacent larger tiles according to algorithms that are applied consistently through a number of iterations. Dart- and V-shaped prototiles have been employed as well, and constructions have been carried through ten generations. The smallest tiles describe complex undulating space curves. The surfaces formed by these f-tilings are in some cases reminiscent of hyperbolic surfaces observed in nature, for example in plants such as green leaf lettuce and in jellyfish. (Received September 16, 2013)

1096-C5-1959 **Douglas Dunham*** (ddunham@d.umn.edu), Department of Computer Science, 320 HH, University of Minnesota Duluth, 1114 Kirby Drive, Duluth, MN 55812-3036. *Patterns with Color Symmetry on Triply Periodic Polyhedra.* Preliminary report.

We have created repeating patterns on triply periodic polyhedra, unlike other artists, such as M.C. Escher who have created such patterns on closed polyhedra. Triply periodic polyhedra are connected polyhedra that repeat in three independent directions in Euclidean 3-space. We consider triply periodic polyhedra that are composed of copies of a regular p-sided polygon, or p-gon and have congruent vertex figures. If there are q p-gons around each vertex, we must have $(p-2)(q-2) > 4$ for the polyhedron to repeat. We call such a polyhedron a {p,q} polyhedron (note p and q do not determine the polyhedron).

Some triply periodic polyhedra form polyhedral approximations to triply periodic minimal surfaces (TPMS). In turn, since TPMS's have negative curvature, their universal covering surfaces have the same large-scale geometry as the hyperbolic plane. Thus a repeating pattern on a triply periodic polyhedron will correspond to a repeating hyperbolic pattern, which we thus call the "universal covering pattern" of the patterned polyhedron.

Our main focus will be to show triply periodic polyhedra with patterns that exhibit color symmetry. That is, symmetries of the polyhedra will induce color permutations on their patterns. (Received September 16, 2013)

1096-C5-2152 **Martha Ellen Waggoner*** (murphy.waggoner@simpson.edu), 701 N C Street, Indianola, IA 50125. *Using Doodles to Teach the Math of Art.*

Simpson's Math of Art class satisfies both the Quantitative Reasoning and the Arts requirements in our general education. The Arts designation for the course requires the students to participate in and reflect on the creation of art. The course attracts students who lack confidence in their ability to create art and who have a narrow idea of what mathematics is.

Using the philosophy of Rick Roberts and Maria Thomas (Zentangles) that "anything is possible one stroke at a time," I use simple doodle-like drawing in class to convince students that they can produce art. At the same time they learn the fundamentals of symmetry, perspective, fractals and other mathematical concepts in art, concepts that stretch their view of mathematics.

I will demonstrate a couple of doodling techniques and the mathematics associated with them, show work that students have produced and provide a link for resources. (Received September 17, 2013)

1096-C5-2154 **Margaret E Kepner*** (renpek1010@gmail.com). *Magic Squares and Their Magic Secrets.* Preliminary report.

Magic squares have intrigued both professional and recreational mathematicians for centuries. In addition to the standard properties that make a particular square array of consecutive integers "magic," other relationships and patterns can be found. I will discuss several 8x8 magic squares that have interesting properties, and explain how I have developed visual expressions of these squares and their magic secrets. The artistic formats I have chosen are inspired by traditional Log Cabin quilt designs, where the specific pattern I have employed alludes to the structure, or history, of each magic square. (Received September 17, 2013)

1096-C5-2224 **Jennifer Wilson*** (wilsonj@newschool.edu) and **Vidhya Kamdar**. *More Mathematics of Pop-up Books.*

The construction and analysis of pop-up books presents a wonderful opportunity to apply concepts from geometry and linear algebra to problems that arise naturally as the "pop-ups" are unfolded. In this talk, a follow-up to a talk on Pop-ups at last year's Joint Meetings, we look at several new simple paper constructions which lead to questions about area and volume, negative space, and rigidity. These can be answered using a combination of mathematical analysis and geometric construction, and provide a fertile opportunity for student exploration. (Received September 17, 2013)

1096-C5-2269 **Sara E Rocha-Juarez*** (sararocha-juarez@my.unt.edu). *Knot Theory: Rational Tangles and Wirtinger Presentations.* Preliminary report.

This paper is structured in a way that simplifi es the general understanding of knots in mathematics and then reinforces that knowledge with an analysis of the complexity of tangles. It introduces some of the basic terms used in knot theory and describes how to work with rational tangles, calculate the fundamental group for different knots, and model Wirtinger presentations. The new results are as follows: Two rational knots are equivalent if and only if one is composed of a tangle with a numerator and a denominator that are prime numbers, and the second knot is composed of a tangle of the numerator, such that a < b and b is one more or less than a multiple of a. The second result shows that even though we assign the virtual operator T(x) to the virtual arcs of a knot in the Wirtinger presentation, the resulting fundamental group may not reflect virtual crossings if the virtual crossings are consecutive. (Received September 17, 2013)

1096-C5-2475 **Darrah P. Chavey*** (chavey@beloit.edu), 700 College St., Beloit, WI 53511. *Symmetry Variation in Hmong Fabric Arts.* Preliminary report.

The Hmong people of Southeast Asia are often classified into 7 sub-groups: White, Green, Blue, Red, Black, Flower, and Striped Hmong. Not surprisingly, they share similar crafts and artwork, and there are certain motifs that easily identify an item as being "Hmong". However, there are certain symmetry structures of these designs that appear to clearly distinguish three of these Hmong sub-groups. With the Hmong "snail" motif, for example, only the Green Hmong traditionally use 2-dimensional symmetry groups (wallpaper groups, or "all-over" designs, as one Hmong artist described them) for their designs. And while these Green Hmong symmetries can include glide reflections, among all the other sub-groups, it seems that only the Blue Hmong use glide reflections in their work. The White Hmong, on the other hand, traditionally use neither of these types of symmetries, but use complex concentric central symmetry arrangements of the motif. Thus while the artistic element, i.e. the motif, distinguishes Hmong fabric art designs from those of other cultures, the mathematical elements of the symmetrical and geometric arrangements distinguish at least three of these sub-groups. We will show several examples of this phenomenon. (Received September 17, 2013)

1096-C5-2578 **William DeMeo*** (williamdemeo@gmail.com). *What does a finite nonabelian group sound like?* Preliminary report.

Underlying many digital signal processing (dsp) algorithms, in particular those used for digital audio filters, is the convolution operation, which is a weighted sum of translations $f(x-y)$. Most classical results of dsp are easily and elegantly derived if we define our functions on $\mathbb{Z}/n$, the abelian group of integers modulo n. If we replace this underlying "index set" with a nonabelian group, then translation may be written $f(xy^{-1})$, and the resulting audio filters arising from convolution naturally produce different effects that those obtained with ordinary (abelian group) convolution.

In this preliminary report we explore the idea of using the underlying finite group (i.e., the index set) as an adjustable parameter of a digital audio filter. By listening to samples produced using various nonabelian groups, we try to get a sense of the "acoustical characters" of finite groups. (Received September 17, 2013)

1096-C5-2660 **Rebecca E. Field*** (fieldre@jmu.edu), MSC 1911, James Madison University, Harrisonburg, VA 22802. *Stumbling towards a pattern: how to make pants.*

Engineering a pair of pants is far more difficult than it sounds. We will start with the most naive approach and see how the constraints of wearability and the shape of the human body change how we see the problem. The topology of the situation is simple, but the geometry gets quite complicated when we have not only negative curvature, but curvature varying from strongly negative to weakly positive. (Received September 17, 2013)

1096-C5-2672 **Karl Schaffer*** (karl_schaffer@yahoo.com). *Dances of Heavenly Bodies: Dance, N-body Choreographies, and Change Ringing.*

Patterns that employ sequences of distinct permutations of dancers are found in dance forms such as English country dance and contra dance, dating at least to the 1600s in England. Contemporaneously in England, the art of church bell change ringing used very similar permutation sequences. More recently, mathematicians and theoretical astrophysicists have discovered that similar patterns are stable orbits for theoretical heavenly bodies under the influence of gravity. This talk explores the connections between these art forms and recent mathematical work as well as two dances choreographed by the author that also make use of these patterns. (Received September 17, 2013)

1096-C5-2682 **David A Reimann*** (dreimann@albion.edu), Mathematics and Computer Science, Albion College, Albion, MI 49224. *Symmetries of generalized Truchet tiles.*

Given a regular polygon, one can subdivide each side into equally spaced segments, with each side containing n node points between segments. A generalized Truchet tile is constructed by connecting unique pairs of such node points using arcs perpendicular to the edge. For a given n, the tiles produced by this procedure create a family of tiles that can be used to create smooth meandering curves in a tessellation. The subgroups of the underlying regular polygon's symmetry group gives all possible symmetries of a tile family. Examples of several generalized Truchet tile families are shown with each tile classified with its symmetry. Chiral pairs are also determined. Because the number of tiles in a family increases exponentially with n, an automated procedure is useful in determining the symmetries of a given tiles. Determining symmetries is critical for creating point symmetric patterns. (Received September 17, 2013)

1096-C5-2690 **William C Linderman*** (wclinder@king.edu). *Sets in Music.*

The term set can be used in music theory to refer to a collection of unordered pitches, possibly in different octaves, represented by distinct integers. For example, the set [0,1,4] could represent the notes C, C#, and E, since C# is one half-step above C, and E is four half-steps above C. In this example, C represents zero, but the set [0, 1, 4] could also represent the notes G, G#, and B where G represents zero. We examine this pattern in some 20th century musical compositions, and we present an original composition for soprano and piano based on this concept of sets. (Received September 18, 2013)

1096-C5-2748 **Elijah M. Allen***, pupilofyah@gmail.com, and **Louis H Kauffman**. *Visualizing the Collatz conjecture.*

Also known as the 3n+1 conjecture, if we iteratively take a positive integer and if it is even divide by 2 and if odd multiply by 3 and add 1 then Collatz conjectures that we will always reach 1. Our approach to this problem is to an image for a given starting number in order to create an intuitive understanding and then using this to fuel the a mathematical understanding. (Received September 18, 2013)

1096-C5-2758 **Elizabeth C Rogers*** (brogers@piedmont.edu), 165 Central Ave, Demorest, GA 30535. *Artists and Their Use of Mathematics.*

Throughout history, art and mathematics have contributed to the function and beauty of civilization. Geometry and numbers were essential for achieving knowledge of the workings of the universe. Thus, they became the vehicle of philosophical thought and found expression in the great works of art. From the works of Da Vinci and Michelangelo to Picasso and Escher, mathematics is distinctly evident in art.

This presentation will focus on proportion and one to four point perspectives and how they have contributed to the beauty and impact of paintings and sculptures. Various artistic pieces from the famous to more obscure will be analyzed based on these mathematical topics. (Received September 18, 2013)

Bridging the Gap: Designing an Introduction to Proofs Course

1096-D1-365 **Connie Campbell*** (campbcm@millsaps.edu), **James Sandefur** (sandefur@georgetown.edu) and **Kay Somers** (somersk@moravian.edu). *Using Video Case-Studies to Develop Proof Writing Skills.* Preliminary report.

The presenters have developed a set of video case studies for use in the teaching of an introductory proofs course. The videos show students who have recently completed an "Introduction to Proof" course as they work in pairs to prove a statement that is new to them. These videos, when used in the classroom together with a well guided discussion, allow students to see peers address obstacles and articulate reasoning as they move toward the proof of a statement (or away from one). This interactive experience allows the viewer a chance to think about how the students in the video are approaching a problem and challenges them to articulate why a particular approach may or may not be working. Engaging in such critique facilitates understanding of the problem-solving process and helps students develop their own proof-writing and reflective-thinking skills.

The presenters will show several clips from their video library and demonstrate how one might use these videos in the classroom to enhance student learning. In addition, they will discuss assessment results related to the use of these videos in the classroom. (Received August 30, 2013)

1096-D1-701 **Frederick M Butler*** (fbutler@ycp.edu), Department of Physical Sciences, York College of Pennsylvania, 446 Country Club Rd., York, PA 17403. *Using Portfolios in an Introduction to Proofs Course.* Preliminary report.

In the Introduction to Proofs course at York College, students are assigned to write approximately 5-7 proofs per week on a variety of topics. Of these, 1-2 are collected and graded by the instructor, and 2-3 are presented by students and discussed by the class. Students are also occasionally paired up to critique each other's proofs. In this way, students receive feedback on the majority of the proofs they have written. At the end of the semester, the instructor selects 10 proofs for which students have received some form of feedback, to be rewritten in a final proof portfolio. Students must include in the portfolio for each proof a first draft, a revised draft, and an analysis of the changes made between drafts. This talk details the evolution that lead to this approach in the course, including things that worked well and things that didn't. (Received September 09, 2013)

1096-D1-1126 **Kate Overmoyer*** (kovermoyer@clarion.edu). *Writing Assignments in an Introduction to Proofs Course.* Preliminary report.

When teaching Introduction to Proofs, I found myself using simple definitions (such as; even/odd integers, divides, and prime numbers) to demonstrate and practice the main proof techniques (direct, by contradiction, and by contrapositive). Although these examples are effective in teaching the techniques, they do not effectively relate the new concepts to those most recently studied, for example, material from the Calculus sequence. In an attempt to bridge this gap, I included a series of writing assignments as part of the syllabus. For example, for one assignment the students wrote a "manual" for solving a mathematical problem and in another they examined proofs from Precalculus and Calculus. In this presentation, I will discuss these assignments as well as how successful I feel they were in improving students' writing, understanding of proofs, and comprehension of previously learned concepts. (Received September 13, 2013)

1096-D1-1150 **Sarah K. Bleiler*** (sarah.bleiler@mtsu.edu). *Evaluating Peers' Arguments as the Catalyst for Learning in an Introduction to Proofs Course.* Preliminary report.

Introductory proof concepts are frequently taught through instructor demonstration, followed by student replication of form and representation to similar problems. When students learn about proof primarily through seeing a "polished" completed proof, they may miss opportunities to make sense of why a particular mode of argumentation (e.g., direct or indirect proof) is appropriate, how a particular mode of argument representation (e.g., visual or symbolic) most clearly communicates a mathematical idea, or when a proof can be considered complete. The purpose of this presentation is to share the design of my introduction to proofs course, where evaluating student arguments served as the primary catalyst for engaging students in making sense of some of these essential proof-writing concepts. Student work was collected before each class session and used to inform the design of subsequent class activities. We worked to establish a communal understanding of what counts as proof. Based on this evolving understanding, students actively engaged in evaluating their peers' arguments, which in turn encouraged them to take a critical stance toward their own proof writing. In this presentation, I share student work and describe class activities that promoted students' learning of proof. (Received September 13, 2013)

1096-D1-1375 **Rachel Esselstein*** (resselstein@csumb.edu), 100 Campus Center, Department of Mathematics and Statistics, Seaside, CA 93955. *Successes and Failures of Inquiry Based Learning in an Introduction to Proofs Course.* Preliminary report.

Inquiry Based Learning (IBL) is a pedagogy consisting of little or no instruction through lecture or readings, rather students are provided with structured problem sets that lead them to discover the material on their own. Over the 2012-2013 academic year, the author implemented an IBL Introduction to Proofs course over two semesters.

The author collected surveys on student attitudes about the course material and their learning in both the IBL version of the course as well as in a traditional lecture version of the course previously taught. Samples of student work were also compared.

In this presentation, the author will share some of the strengths of her IBL Introduction to Proofs courses (e.g. students demonstrated improved problem solving and independence of thought) as well as some of the issues that arose in the IBL courses (e.g. student anxieties about what they did not understand). The author will then outline steps being taken to create a hybrid lecture/IBL course that encompasses the best of both teaching styles. (Received September 15, 2013)

1096-D1-1639 **Katherine J. Mawhinney*** (mawhinneykj@appstate.edu), 330 Walker Hall, 121 Bodenheimer Dr., Boone, NC 28608. *Using Formal and Informal Proof Writing in an Introduction to Proofs Course.*

The *Techniques of Proof* course at Appalachian State University includes propositional and predicate calculus in the axiom systems of L and K. This exploration into formal axiomatic systems is intended to build students' ability to create logical arguments that are concise and complete, by focusing on the structure and sequencing of logical formulas. The structure and sequencing of formulas is then connected to mathematical proofs beyond the formal axiomatic systems, as students write proofs about specific mathematics content. Another benefit of the exploration is that it acts as a bridge from traditional student practices to mathematical practices, by providing a manageable number of building blocks with which students can prove many logical statements. This session will highlight some of these connections along with the inquiry-based nature of exploration in L and K. Student opinion on the usefulness of the course in the transition to advanced mathematics courses will also be shared. (Received September 16, 2013)

1096-D1-1752 **William W. Johnston*** (bwjohnst@butler.edu), Butler University, 4600 Sunset Ave., Indianapolis, IN 46208. *Introduction to Proofs as A Survey Course in Mathematics.*

This presentation describes the effects on students of teaching the Proofs course as a survey of seven different mathematical subfields and its resulting impact: an increased number of majors at two institutions where its design has become standard. The choice of subfields includes mathematical logic, which importantly begins the course's outline and thus promotes logic (1) as an interesting study in its own right but also (2) as a foundation on which mathematical proofs can be based. The design then flows through abstract algebra, number theory, real analysis, graph theory, probability, and complex analysis, incorporating overarching themes to provide segues from one subfield to the next. The impact is widespread. For example, the small "tastes" students get of any one topic sets up better success in the upper level curriculum. Students also report the course design helps them choose elective majors courses in a more informed manner. A strikingly large percentage of students taking this course design end up declaring mathematics as a major. (Received September 16, 2013)

1096-D1-1982 **Susanna S. Epp*** (sepp@depaul.edu). *The Evolution of an Introduction to Proofs Course.*

When I first started teaching an introduction to proofs course in 1978, I thought that having an entire course that carefully developed the basics about set properties, functions, and relations would solve the problem of student unpreparedness for courses like abstract algebra and real analysis. Although I believe that even the initial offering of the course was helpful, over the years I've made many changes. Most have been in response to discoveries that my assumptions about what students would find easy were contradicted by their work. The majority concern student difficulties with logic and language, especially in connection with quantified statements. A small example: Relatively recently I became aware that when I ask students to use other words to explain the meaning of the sentence "The negative of any rational number is rational," a surprising number respond by writing something meaningless. Although they usually express dissatisfaction with what they wrote, they genuinely don't seem to understand what the sentence means. In this talk I will share many of the discoveries I've made and the resulting changes in the course. I will also discuss the problem of convincing students that it is important to use careful language when writing proofs and disproofs. (Received September 17, 2013)

1096-D1-2104 **Clark Wells*** (wellsc@gvsu.edu), Dept. of Mathematics, Grand Valley State University, 1 Campus Dr., Allendale, MI 49426. *Teach What You Do.*

The bridge course at Grand Valley State University has been good at helping students learn how to write proofs, and this is a good thing. There is always room for improvement, and I contend that improvement in one particular skill could result in huge improvements in student success, with little loss (even gains!) in proof writing ability. That is the skill of *conjecturing*.

One goal of a bridge course, I suggest, should be to help students understand what mathematics really is. And really, which is it that mathematicians spend more time on, writing final proofs, or coming up with and refining conjectures?

Furthermore, a serious issue that continues to come up in our courses is ritualistic understanding of proof. I think students see proofs as jumping through hoops because they don't really see the value in proving things they know are true.

In this talk I will offer practical suggestions on generating student buy-in for what is likely to be a very different course from their experience as well as share several activities and methods of assessment that both give students authentic experience of what it is to do mathematics, and support them in learning to develop, refine, and communicate their results. (Received September 17, 2013)

1096-D1-2132 **Ockle E Johnson*** (ojohnson@keene.edu), Mathematics Department, Keene State College, Keene, NH 03435. *Integrating the Elements of an Introductory Proof Course.*

Many introductory proof texts and courses begin with logic and sets. This semester we began with a proof I once introduced to my daughter's first grade class. As we continued with elementary number theory proofs, we were soon forced to consider logic and logical equivalences. An axiomatic development of the natural numbers and the integers introduced the inherent inductive nature of the natural numbers before dealing with proof by induction, reinforced the basic properties of the operations, and led to a consideration of sets and relations. In this talk we will discuss the strengths and weaknesses of this approach and the lessons learned. (Received September 17, 2013)

1096-D1-2266 **Kristin A. Camenga*** (kristin.camenga@houghton.edu), Houghton College, 1 Willard Avenue, Houghton, NY 14744. *Developing community norms for proof: forum discussions of the nature and import of proof.* Preliminary report.

Proof is central to the mathematical community, not just as a mechanical form but as a means of knowing and communicating. How can a transition course help students understand the nature and import of proof in the mathematical community as well as the mechanics? We share forum assignments and discussions from a 7-week Introduction to Proof class which are intended to place the students' work with proof in a larger context and help form their attitudes toward proof. Discussion topics include the nature of proof, how it is communicated, and mathematical beauty. We believe these assignments also support students' motivation and minimize frustration in the process of learning the mechanics of proof. (Received September 17, 2013)

1096-D1-2418 **Susan Crook*** (susan.crook@loras.edu), 1450 Alta Vista St., Box 141, Dubuque, IA 52001. *How important is the final answer? : Using inquiry-based learning in an introductory proofs course.*

Students enter their introductory proofs course accustomed to being able to check their final answers with others and in the back of the book. One of the greatest difficulties encountered in teaching proofs is helping students adapt to the idea that there are many correct answers. While in computation-based courses, most students can memorize algorithms and do satisfactorily on tests, a certain level of understanding is required to create a correct proof. While teaching my first intro proofs course and my first inquiry-based learning course, I often fought with when to assist students and when to let them struggle just a bit longer on a proof. The line between frustration and giving up can be hard to see until your students have crossed it. In inquiry-based learning classes it can be especially hard to figure out how to give input without positioning yourself as the authority on the subject. I will discuss my observations on the issue and what worked for my class. (Received September 17, 2013)

1096-D1-2440 **Jim Fulmer*** (jrfulmer@ualr.edu), Department of Mathematics & Statistics, University of Arkansas at Little Rock, 2801 South University Avenue, LIttle Rock, AR 72204-1099, and **Tom McMillan**, Department of Mathematics & Statistics, University of Arkansas at Little Rock, 28, Little Rock, AR 72204-1099. *Using an Inquiry-Based Learning Approach in Introduction to Proofs and Advanced Calculus Courses.* Preliminary report.

This presentation describes using an inquiry-based learning approach in two mathematics courses at the University of Arkansas at Little Rock, Intro to Proofs and Advanced Calculus. Two mathematics department faculty members were involved in developing these courses with the IBL approach. Our talk will cover warm-up activities (challenge problems to get the students comfortable working together), and the approaches we used in class to encourage students to write their proofs and work problems in a group setting, and to gain confidence in their abilities to communicate with others. The primary textbook for both courses was a set of class notes, one on Intro to Proof and the second on Advanced Calculus. Both courses represented a trial run, which proved successful. As a result, Introduction to Proof, is now required at the sophomore level for all mathematics majors and Advanced Calculus is required for some of our degree programs. The authors express their appreciation to the Educational Advancement Foundation for financial support, and to Mike Starbird and his colleagues at the University of Texas at Austin for generously allowing us to attend well-established and well-designed inquiry-based learning classes on their campus. (Received September 17, 2013)

Data, Modeling, and Computing in the Introductory Statistics Course

1096-D5-85 **Murray H. Siegel*** (murray.siegel@asu.edu), Math & Science Faculty, SLS, Polytechnic Campus, Mesa, AZ 85212. *A Semester Project for Introductory Statistics.*

A meaningful introductory statistics class should include one project. This presentation describes a project that counts towards twenty percent of the semester grade. Students are required to submit a proposal for two binomial probability experiments, each using the same physical tool. One has a relatively low probability (LP) of success (15-25%). The other has a relatively high probability (HP) 55-75%. Once a proposal is accepted, the student conducts 40 samples of sample size 30 for each experiment. Thus the student is running 2400 events. When complete, a frequency distribution of the data is submitted. Once this is accepted, the student writes a report that analyzes the two experiments. The report includes a justification that each experiment was binomial; a comparison of center and spread, and an analysis of shape; an evaluation of the normality using the Empirical Rule; a 95% confidence interval for the mean number of successes for each experiment; a hypothesis test on the difference between means; and a discussion of the results. The discussion answers questions such as what causes the differences between experimental and theoretical results and a further evaluation of the underlying distribution. (Received July 18, 2013)

1096-D5-101 **Sue B Schou*** (schosue@isu.edu), PO Box 4043, Pocatello, ID 83205. *Data Visualization Using Minitab, Google Fusion Tables, and Tableau.* Preliminary report.

Any data analysis should begin by learning about the data visually. Various tools for visualization exist but should be accessed based upon the data visualization needed. Minitab has an excellent tool for visualizing probabilities and their distributions as well as tools for standard graphical analysis while Google fusion tables can be used to visualize data geographically. Tableau is specifically designed for “big data” manipulation and visualization. The purpose of this presentation will be to engage the audience in learning about new ways to analyze and visualize data with the best tools currently available. Specific instructions will be discussed and a variety of data sets examined. At the end of the discussion, details about how to access these tools will be made available. Minitab has a very reasonable university wide licensing fee for the full professional version. Google makes fusion tables available to universities by requesting the app be added to Gmail and Tableau offers free access to universities as well. (Received July 29, 2013)

1096-D5-402 **Majid Masso*** (mmasso@gmu.edu), 10900 University Blvd. MS 5B3, Manassas, VA 20109. *Predicting Drug Resistance: Probability and Statistics Meet the Building Blocks of Proteins.*

Put away the dice and bag of balls, and consider structural biology examples! This talk begins with the 20-letter amino acid alphabet, which are protein building blocks. A protein has hundreds of consecutively linked amino acids, selected with replacement, forming a unique sequence of letters. The linear chain folds like a balled-up thread into a precise 3D structure, held together by interactions between spatially close amino acids often distant in the sequence. These basic ideas are sufficient to begin work on methods of enumeration, probability distributions, and log-likelihoods.

We developed a technique that generates a distinct feature vector to represent each mutated form of a protein due to amino acid changes. This approach was applied to nearly 500 mutants of the HIV-1 protease enzyme whose altered susceptibilities to the FDA approved drug ritonavir were quantified with a time consuming and expensive assay. By implementing classification and regression statistical learning algorithms, the data set was used to train models for accurately predicting ritonavir resistance in new protease mutants isolated from patient viruses. Since the models are fast and cost-free, they could be used as supplementary diagnostic tools. Our strategy extends to other commercial drugs. (Received September 02, 2013)

1096-D5-849 **Catherine Case*** (ccase@ufl.edu), **Melanie Battles** (m.battles@ufl.edu) and **Tim Jacobbe** (jacobbe@coe.ufl.edu). *Toward a Conceptual Understanding of P-values: The Advantages and Challenges of Randomization-Based Inference.*

Before modern computing power allowed for rapid simulations, introductory statistics courses necessarily relied on methods like z tests and t tests to introduce the core logic of inference; today, a growing number of statistics educators (e.g., Cobb, 2007) are proposing that these traditional methods be replaced or supplemented with randomization-based tests which more directly model the randomness inherent in the study design. To explore whether conceptual understanding of p-values could be improved by exposure to randomization-based inference, we conducted lessons in which students familiar with traditional inference methods used physical and computer simulations to estimate p-values. To assess the impact of the lessons, we prompted students to write brief explanations of p-values without relying on statistical jargon, to apply these explanations in different contexts, and to self-evaluate their understanding before and after participation. Citing previous research and examples of student responses, we will present our findings on students' varying conceptions of p-values. We will also suggest possible modifications to the simulation activities to address enduring misconceptions and the particular challenges of randomization-based inference. (Received September 10, 2013)

1096-D5-894 **Kimberly A Roth*** (roth@juniata.edu). *Using Genomics Data in Introduction to Probability and Statistics.*

Juniata College has a Genomics Leadership Initiative funded by the Howard Hughes Medical Institute and the National Science Foundation. As part of the initiative students can take a selection of courses to receive a genomics certificate. One of the possible classes they can take is Introduction to Probability and Statistics. As part of the grant, I am going looking for genomics based examples and data sets that I can incorporate into the class. I will talk about what I have found and what I am seeking still. (Received September 11, 2013)

1096-D5-1612 **Julie A. Belock*** (jbelock@salemstate.edu), Mathematics Department, Salem State University, 352 Lafayette St., Salem, MA 01970. *P-Values Through Simulation.*

Understanding the logic of p-values can be challenging for introductory statistics students. I will share lab activities and classroom demonstrations that use simulations to help students interpret p-values and understand their purpose. Minitab is used in these activities, but they are easily adaptable to other software or even graphing calculators. (Received September 16, 2013)

1096-D5-1671 **Grant L Innerst*** (gi7584@ship.edu), 3588 Stine Hill Road, Red Lion, PA 17356, and **Ben Galluzzo** (bjgalluzzo@ship.edu), Shippensburg University, Department of Mathematics, Shippensburg, PA 17257. *Statistical Crowd Counting.*

Money, tourism, and regional visibility are just a few reasons street fairs are extremely important to the towns that host them. Many festivals tout attendance numbers to attract vendors and, in turn more attendees, but are these numbers accurate? This project requires students to collect data and then analyze it using standard statistical tools with the goal of developing a mathematical model for approximating the number of people attending non-ticketed, open-air events. In this talk, we will discuss how this experiential learning activity fits into the introductory statistics curriculum and how using real-world (occasionally "messy") data provides students with additional insight into the use of statistics outside the classroom. (Received September 16, 2013)

1096-D5-1770 **Nicholas J Horton*** (nhorton@amherst.edu), Amherst College, Department of Mathematics, Box 2239, Amherst, MA 01002, and **Benjamin S Baumer** and **Hadley Wickham**. *Big Data in the Intro Stats Class: Use of the Airline Delays Dataset to Expose Students to a Real-World, Complex Dataset.* Preliminary report.

Students in the introductory statistics course need exposure to bigger datasets and more complex questions to be able to make sense of the increasingly data-centric world that they will inhabit. In this talk, I will describe how the airline delays dataset (150 million records on all commercial flights in the US from 1987 to 2012) can be integrated into the introductory statistics course. This large dataset is introduced early in the semester through a model eliciting activity due to Garfield and colleagues that leads students to undertake informal inference when comparing the on-time performance of two airlines servicing a pair of airports. Later in the course, students are able to assess the performance of their comparison rule by repeatedly sampling from the underlying population of flights, as well as visualizing the population using straightforward commands in R to access the database using simple SQL commands. The techniques are facilitated by use of R Markdown. In addition to providing insight into flight delays, the activity helps expose students to the power of statistics to make decisions in the face of uncertainty. (Received September 16, 2013)

1096-D5-1887 **Phong Le*** (ple@niagara.edu), Mathematics Department, Niagara University, NY 14109. *Using Faculty Research as a Teaching Tool In Statistics.* Preliminary report.

The goal of this project is to incorporate faculty research into the teaching in introductory level statistics. Using the research of well-known faculty on campus who use statistics in their research we investigate whether we can foster an increased interest in statistics as well improve understanding of the diverse applications of statistics. When possible, raw data was also obtained to allow students to recreate original research. A secondary goal is to give the students a better understanding of the rigors and pitfalls of experimental design and observational studies. How the papers were chosen, student reactions to the activities and impact of the project will all be discussed. (Received September 16, 2013)

1096-D5-2230 **Shonda R Kuiper*** (kuipers@grinnell.edu), 1116 8th Ave, Grinnell College, Grinnell, IA 50112. *Designing Simulated Experiments in the Introductory Statistics Course.*

This is the culmination of a three year National Science Foundation Grant, DUE TUES #1043814, which focused on the development and implementation of web-based games and corresponding investigative laboratory modules (labs) to effectively teach statistical thinking and the process of scientific research. We demonstrate game-based labs that follow the GAISE guidelines and bridge the gap between short, focused homework problems and the open-ended nature of a research project. This presentation will focus on one game-based lab where students design and conduct a study to determine whether factors such as location, time of day, price, type of music, or some combination of these influence sales in a small business. These game based labs provide project-based materials that emphasize real-world applications and conceptual understanding. These materials are designed to show students early in their academic career the importance of proper data analysis in any discipline. (Received September 17, 2013)

1096-D5-2305 **Rodney X. Sturdivant*** (sturdivant.11@osu.edu), **Shonda Kuiper** and **Kevin Cummiskey**. *Playing and Getting "Messy" with Data.*

Decisions about data cleaning and how to handle violations of statistical assumptions can have great impact on the validity of conclusions in real research studies. Unfortunately, in typical introductory statistics course students are not forced to make such decisions or to wrestle with the implications. During the course of a three year National Science Foundation Grant, DUE TUES #1043814, we developed and implemented web-based games and corresponding investigative laboratory modules (labs) to effectively teach statistical thinking and the process of scientific research. We found a bonus in that several of the lab data sets have "messy" features and force students to carefully consider the role of underlying statistical assumptions. In addition to being engaging for the students the impact of data cleaning and violations of model assumptions were made more relevant in classroom testing. We discuss the use of two of the games and associated guided lab in introducing students to issues prevalent in real data and the challenges involved in data cleaning and dangers when model assumptions are violated. (Received September 17, 2013)

1096-D5-2335 **Eric Ruggieri*** (eruggier@holycross.edu), College of the Holy Cross, Dept. of Mathematics and Computer Science, 1 College Street, Worcester, MA 01610. *Visualizing the Central Limit Theorem through Simulation.*

The Central Limit Theorem is one of the most important concepts that we teach in an introductory statistics course, yet it may be the least well understood by our students. Sure, our students can plug numbers into a formula and solve problems, but conceptually, do they really understand what the Central Limit Theorem is saying? In this talk, I will demonstrate a simulation that I have developed which illustrates the Central Limit Theorem under various assumptions about the shape of the population distribution. Afterwards, I'll describe an assessment used to check the student's understanding of this crucial concept. (Received September 17, 2013)

1096-D5-2427 **Patricia B Humphrey*** (phumphre@georgiasouthern.edu), Dept. of Mathematical Sciences, PO Box 8093, Georgia Southern University, Statesboro, GA 30460-8093. *Modeling – It's harder than you might think.* Preliminary report.

Data mining and modeling are generally "hot topics" of late. Getting these "right" is not easy. (How often have you entered a search on Amazon and gotten totally unrelated items showing?) Even analyzing data from a "simple" experiment can be fraught with pitfalls and dangers. I believe students must walk before they can run, so modeling in my Intro courses starts slowly. My Introduction to Statistics II course has an assignment to use our software of choice, Minitab to model the "value" of houses in the Statesboro area. I'll also discuss the challenges involved in an investigation modeling the rate of leaf decay under different conditions. The latter was a joint project involving a local high school STEM class, GSU Biology faculty, and myself. (Received September 17, 2013)

1096-D5-2541 **Marsha J. Davis*** (davisma@easternct.edu), Department of Mathematics, Eastern Connecticut State University, 83 Windham Street, Willimantic, CT 06226. *Against All Odds: Inside Statistics.*

Given the importance of statistics and statistical reasoning in an increasingly complex and information-rich world, ways must be found to engage students with real-world contexts and activities that support learning the basic elements of statistical thinking and the important concepts that underlie statistical reasoning, particularly concepts that students find difficult. Online resources from the newly released *Against All Odds* (*AAO*): *Inside Statistics* (funded by Annenberg and the Consortium for Mathematics and Its Applications (COMAP)) are designed to do just that. The videos, activities, interactive applets, exercises, and written support material in

AAO provide a rich learning environment that makes statistics come alive and promotes deeper understanding. This presentation will focus on a video segment and related class activities that rely on simulated data produced by the Wafer Thickness applet. Results from class testing will be shared with participants. (Received September 17, 2013)

1096-D5-2627 **Sarah L. Mabrouk*** (smabrouk@framingham.edu), Framingham State University, 100 State Street, PO Box 9101, Framingham, MA 01701-9101. *Using an Ever-Growing Data Set in an Introductory Statistics Course.*

In an effort to have students experience the application of statistics from data collection to hypothesis testing, I provide my students with 1.69-ounce bags of Milk Chocolate M&M's, three bags per student in most classes. The students determine the frequencies for the colors of the candies in their sample bags, and the class data is compiled and, then, analyzed throughout the semester using the statistical methods that students learn throughout the course. Combining class data with the data from my other course sections as well as with that from past classes has produced an ever-growing data set consisting of over six-hundred samples. In this presentation, I will discuss my use of this ever-growing data set in my introductory statistics classes as well as the technology used to analyze the data, the in-class analysis, and associated outside-of-class assignments. (Received September 17, 2013)

Flipping the Classroom

1096-E1-18 **Jenna R Van Sickle*** (jenna.vansickle@gmail.com), 6800 Wydown Blvd, St Louis, MO 63105. *Adventures in flipping my college algebra classroom.*

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 Lecture Capture 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, and what I would do differently for future courses. (Received May 01, 2013)

1096-E1-55 **Katrina Palmer*** (palmerk@appstate.edu), 121 Bodenheimer Dr, 331 Walker Hall, Boone, NC 28608. *Does Flipping a Calculus Class Really Work?* Preliminary report.

Flipping the classroom swaps the roll of lecture and homework. By flipping the class, I hoped students would be more successful and that they would achieve a higher level of thinking (compared to previous semesters). This presentation will address what I've learned while flipping 4 Calculus I classes, and will share results. (Received June 26, 2013)

1096-E1-63 **Jacqueline A Jensen-Vallin*** (jacqueline.jensen@sru.edu). *Flipping Intermediate Algebra.*

In the Spring 2013 semester, my course load included intermediate algebra for the first time since graduate school. My teaching style has developed into something very student-centered, and so I entered the course giving mini-lectures and then having the students complete problems (with my support) in groups during class time. The students were so bored during the 10-15 minute mini-lectures that in Fall 2013, I decided to flip the classroom entirely. We will discuss the details of this transition, student feedback, and compare student performance in these two settings. (Received July 02, 2013)

1096-E1-169 **Brian J Winkel*** (brianwinkel@hvc.rr.com), 26 Broadway, Cornwall, NY 12518. *Sylvanus Thayer Flipped Out – Method Ahead of Its Time.* Preliminary report.

Sylvanus Thayer is dead, but the Thayer Method of teaching – modified as with all things – lives on at West Point. We discuss how students come to class prepared from reading and attempted scaffolded activities before class and how that energizes the classroom activities and learning. We show how such a method works in a mathematical modeling course in which students are to prepare some initial inquiries into a modeling scenario before class and then develop a more sophisticated and solid model through classroom interactions under the guidance of a classroom teacher. (Received August 12, 2013)

1096-E1-328 **Albert Schueller*** (schuelaw@whitman.edu), 345 Boyer Avenue, Whitman College, Walla Walla, WA 99362. *"Social reading" in the mathematics classroom.*

We will discuss the use of the Classroom Salon "social reading platform" in the mathematics classroom (Calculus in particular). This innovative tool allows students to read and annotate the textbook on-line prior to class in a social context where they can view and respond to comments from the other members of the class. The instructor can view the annotations and use them to guide lecture/discussion in class. Experiences and observations from using this system to teach two sections of Calculus I during the Fall 2013 semester will be shared. (Received August 28, 2013)

1096-E1-333 **Reza O. Abbasian***, Texas Lutheran University, 1000 West Court Street, Seguin, TX 78155, and **John T. Sieben** (jsieben@tlu.edu), Texas Lutheran University, 1000 West Court Street, Seguin, TX 78155. *Several Devices and Software for Creating Math Videos.*

Creating Math videos is the first step in designing a flipped classroom. In our talk we will discuss two platforms: PCs with ad-on graphics and tablets such as iPad and related hardware. Then we will present several popular software packages that work with those devices. We will then discuss the cost, advantages and pitfalls of each device and related software.

In the first segment of our presentation we will be demonstrating the details of creating short videos using a Wacom INTOUS pen-tablet plus Camtasia software on a PC. In the second part of our talk we will show the audience the details of creating short videos using Doceri software plus a stylus pen with an iPad. We will end the talk by introducing several other software options such as Notability. Our presentation is intended for mathematics and/or statistics educators with interest in using instructional videos and flipped classroom approach to teaching. (Received August 28, 2013)

1096-E1-398 **Christopher Oehrlein*** (coehrlein@occc.edu), Oklahoma City, OK. *Making Yourself the Lead Vocalist among many Secondary Sources in Flipped and Blended Differential Equations Courses.*

A first course in Differential Equations may take on many personalities. It can be focused anywhere on a scale from purely procedure-based to extremely concept-based. It can include many different types of equations or focus on very few. It may include systems, Laplace transforms, nonlinear equations and series solutions. Assessment could focus on the content of problem solutions or the end answers. How the instructor designs around these issues should also guide the students in their preparation for class, understanding of the material, studying for exams, and presentation of work. In the current climate of using packaged resources and other peoples' online notes and videos in flipped and blended courses, the students' primary source – their instructor – too often gets ignored and takes on the role of Navigator (with some assessment authority). Instructors can easily create supplemental resources that show and tell students how they want content understood and work presented. Students who see their own instructor's handwriting and hear their own instructor's voice feel a more personal connection to the material and ultimately to the course. Knowing that their instructor invested time and energy goes a long way in convincing the students to invest more in the course themselves. (Received September 01, 2013)

1096-E1-419 **Scott A. Stevens*** (stevens@champlain.edu), Champlain College, 163 South Willard Street, Burlington, VT 05402. *Intro Stats - To Flip or Not to Flip?* Preliminary report.

The idea of a flipped classroom is provocative and unnerving. I like the idea of spending more class time doing problems and less time lecturing. Conversely, I'm not convinced all of my students can obtain sufficient knowledge outside of class to successfully get started on problems during class. For the Fall 2013 semester I am teaching four sections of mid-day Introduction to Statistics courses. I'm teaching two of these sections using the flipped classroom approach and the other two sections are taught in a more, but not quite, traditional lecturing method. All sections use the same book, do the same online homework problems, and take the same tests in class. So far, the flipped classes seem to be doing as well as the traditional classes and these students seem to be enthusiastic about the method. This presentation details how I conduct a flipped classroom and gives a full report on the differences in student performance and sentiments. I will also describe how the text and associated online supplements help facilitate the flipped classroom approach. At the time of writing this abstract, I am not convinced one approach is better than the other but I am curious to see if it works and how well. (Received September 03, 2013)

1096-E1-623 **Joseph Petrillo*** (petrillo@alfred.edu). *Flipping the Calculus Classroom.*

The Alfred University Calculus Initiative (AUCI) is a flipped calculus course that combines a new and strategic curriculum with an active-learning classroom, short video lessons, and online quizzes and homework. The goal

of the AUCI is to improve understanding of and success in first-semester calculus while maintaining the level of rigor and breadth required for more advanced courses. This project is supported by the National Science Foundation under grant number DUE-1140437.

In this talk, we will provide descriptions and results of past and ongoing controlled studies that focus on the effectiveness of the new curriculum and the flipped classroom. In particular, we will report on data analysis of final exam grades, survey responses, and results of the Calculus Concepts Inventory. (Received September 08, 2013)

1096-E1-639 **Jianfeng Zhang*** (zjfccb@gmail.com), Chattanooga State Community College, 4501 Amnicola Hwy, Chattanooga, TN 37406. *Flipping the Classroom—Creating an Active Learning Environment.*

The flipped classroom inverts traditional teaching methods, delivering instruction online out-of-class and moving homework in-class. This paper talks about the facts of flipping teaching based on author's experiences. It demonstrates the implementation for both out-of-class and in-class. The outcomes are reported and future improvements are discussed. It also provides some details for creating videos. (Received September 08, 2013)

1096-E1-800 **Priya Shilpa Boindala** (pboindal@ggc.edu), 1000 University Center Ln, School of Science and Technology, I-2122, Georgia Gwinnett College, Lawrenceville, GA 30043, **D Natasha Brewley*** (dbrewley@ggc.edu), 1000 University Center Ln, School of Science and Technology, A 1601, Georgia Gwinnett College, Lawrenceville, GA 30043, **Jennifer L Sinclair** (jsincla1@ggc.edu), 1000 University Center Ln, School of Science and Technology, I-3101, Georgia Gwinnett College, Lawrenceville, GA 30043, and **Keith A Erickson** (kerickso@ggc.edu), 1000 University Center Ln, School of Science and Technology, A 1480, Georgia Gwinnett College, Lawrenceville, GA 30043. *'Flipping' the Pre-calculus classroom: From ideation to execution.* Preliminary report.

We redesigned a PreCalculus course to fit the "flipped" classroom model where students would have an increased opportunity to engage in meaningful classroom experiences so that they can make connections to mathematics content across disciplines. A total of four Pre-Calculus classes were "flipped" - 2 in Fall 2013 and 2 in Spring 2014. In this presentation we will highlight and describe:

- our vision and the reason for choosing Pre-Calculus as a candidate for "flipping"
- the background research and preparatory work (such as the backward course re-design process, the significant learning goals and components of the flipped model implemented, the activities developed, student and faculty surveys, course template and choice of interactive technology)
- the structure of the course
- the technology used to engage students daily in class.
- the active learning strategies implemented
- the quantitative and qualitative assessment results

We believe that this road map will be beneficial to anyone interested in "flipping" a course. This ongoing work is funded by STEM Initiative II Grant from the USG Board of Regents. (Received September 10, 2013)

1096-E1-896 **Miriam Harris-Botzum*** (mharrisbotzum@lccc.edu), 4525 Education Park Drive, Schnecksville, PA 18078. *Intermediate Algebra: A First Attempt at Flipping a Classroom, and the Lessons Learned.* Preliminary report.

In the spring semester of 2013, I participated in an experiment on my campus using "Classroom Capture" to record lectures and make them available to students for review, using a classroom website. In the fall semester, I used these same videos for a new experiment: Flipping a classroom. Because I was teaching multiple sections of the same Intermediate Algebra course, I was able to conduct a somewhat controlled experiment, which is currently underway as of the time this abstract is being submitted. All sections used a standard, primarily lecture-based approach for the first unit, to establish a baseline comparison between classes. For the second and third units, one section was flipped. The students in that section were expected to watch the videos prior to coming to class; in class, they worked on the "homework", using the same assignments as the other sections; they were also assigned additional projects to complete during class time. This talk is a preliminary report that will analyze the results of this experiment, and discuss student compliance, student attitudes, and successful completion rates of the experimental and control sections. (Received September 11, 2013)

1096-E1-904 **Peter L Staab*** (pstaab@fitchburgstate.edu), Department of Mathmematics, 160 Pearl St., Fitchburg, MA 01420. $f^{-1}(Calculus\ I)$ *: how and why I decided to flip the Calculus classroom.* Preliminary report.

In both semesters of last academic year I taught Calculus I by flipping the classroom. I provided my student's videos of lectures of all material, expected them to watch the video and come to class ready to do problems. This talk will focus on why I decided to do this and the nuts and bolts of how I did this as well as some preliminary analysis of the effects. (Received September 11, 2013)

1096-E1-1008 **Rachel Levy*** (levy@hmc.edu) and **Darryl Yong**. *Probing the Inverted Classroom: A Multi-year Multi-department Controlled Study.*

We have launched a study of the inverted classroom in Mathematics, Engineering and Chemistry courses. The goal of this quasi-experimental study is to measure the effect of instructional method (inverted or active lecture) on student learning and attitudes, while controlling for as many other variables as possible. In this talk we will describe the study protocol: our modes of instruction, how we measure learning and affective gains, and how we track student outcomes in downstream courses. In addition, we will share preliminary analysis based on data from the first year of our study and how we will use this data to improve instruction. This work is financially supported by our college and the National Science Foundation TUES program. (Received September 12, 2013)

1096-E1-1025 **Bryan Dawson*** (bdawson@uu.edu). *The Best of Both Worlds: The Flipped Classroom with a Moore Method Flavor for Undergraduate Analysis.*

Proof-based courses such as an undergraduate introduction to analysis are often run in one of two ways: lecture or Moore-method. The daily professor-student interaction of the Moore method tends to help the students develop skills more deeply than is typical for a lecture class, but usually at the sacrifice of breadth of topics covered. Since students preparing for graduate school benefit from depth of skills but are generally expected to also have a breadth of knowledge, it has often been difficult to choose between the two competing options. Thankfully there is now a third option!

This talk will describe my experience offering introduction to analysis using a flipped classroom during fall 2013. The presentation will include the method and technology used for recording lectures (mostly pencasts with an occasional screencast), the Moore-method flavor to the class meetings, student reaction, and an informal review of the impact on student learning. (Received September 12, 2013)

1096-E1-1041 **Perry Y.C. Lee*** (plee@kutztown.edu), Lytle Hall 267, Department of Mathematics, Kutztown University of Pennsylvania, Kutztown, PA 19530. *Engaging College Algebra Students via the Flipped/Inquiry-Based Learning Approach in a 'Large' Classroom Setting.*

Inquiry-Based Learning (IBL) in a mathematics classroom has shown to be very effective for engaging students in the understanding of the material. That is, students interact with peers and the instructor by asking questions and conjecturing (by doing mathematics) rather than sitting, listening, and taking notes in a traditional classroom setting. Recently, 'flipped' approach to courses has become a method of teaching receiving attention, and these courses seem to be effective in the use of classroom time, especially for large classroom settings.

The author has incorporated both the flipped and the IBL (or F/IBL) approach for managing and engaging students in his 'large' College Algebra classroom this past Fall 2013 semester which mainly consisted of college freshmen. MyMathLab was used for students to understand material and do homework assignments outside the classroom; whereas, students (who were in groups) presented solutions on the board by interacting with peers and the instructor inside the classroom setting.

This talk will address and highlight the author's experiences including the structure of this F/IBL course; the overwhelming benefits that came with this approach for this course; and some pitfalls for teaching mainly college freshmen of a 'large' classroom size. (Received September 12, 2013)

1096-E1-1149 **Randall E Cone*** (conere10@vmi.edu), 439 Mallory Hall, Virginia Military Institute, Letcher Avenue, Lexington, VA 24450. *The Mathematics Laboratory and Student Presentations in Pre-Calculus.*

One simple mechanism by which we may include Active Learning (AL) and Inquiry-Based Learning (IBL) into an undergraduate pre-calculus course is the student presentation. In addition, reconfiguring classroom activities to resemble a more laboratory-style setting brings additional opportunities for IBL, and forms a strong variation of the flipped classroom. Over the last three years we have developed a series of Pre-Calculus laboratory worksheets which blend traditional procedural practice with AL and IBL activities. At our institution, combining regular classroom student presentations, a semi-traditional worksheet series, and a laboratory-style classroom environment has had a positive impact on student perception of mathematics as well as resulting in higher success rates in later calculus classes. In this talk, we discuss the history and development of our Mathematics Laboratory Pre-Calculus course, its positive aspects, pitfalls, and possible future changes. (Received September 13, 2013)

1096-E1-1207 **Sarah Abramowitz** and **Kathleen Madden*** (kmadden@drew.edu), Department of Mathematics & Computer Science, Drew University, Madison, NJ 07940. *A Flipped Course Version of Introductory Statistics - Part I.* Preliminary report.

At Drew University, introductory statistics is being taught with a completely flipped class approach. New material is introduced via assigned videos, freeing up class time for group problem solving, projects, and class discussion. In this first of two talks, we will describe the mechanics of creating and implementing the course (i.e. creating the videos, the role of course management software, in-class activities, etc.). (Received September 13, 2013)

1096-E1-1210 **Sarah Abramowitz*** (sabramow@drew.edu) and **Kathleen Madden**, Department of Mathematics & Computer Science, Drew University, Madison, NJ 07940. *A Flipped Course Version of Introductory Statistics - Part II.*

At Drew University, introductory statistics is being taught with a completely flipped class approach. New material is introduced via assigned videos, freeing up class time for group problem solving, projects, and class discussion. In this second of two talks, we will discuss our motivation for using the flipped course method and the assessment that we have done of its effectiveness. (Received September 13, 2013)

1096-E1-1238 **Karen M. Bliss*** (karen.bliss@quinnipiac.edu), 275 Mount Carmel Ave, CL-AC3, Hamden, CT 06518. *Group Work & Modified Moore Method in Flipping Calculus 1.* Preliminary report.

This talk will address issues and lessons learned in two semesters of flipping the calculus 1 classroom. The first attempt at flipped calculus entailed having the students work in groups during class after having watched online lessons. While there were positive outcomes to this approach, I found that students did not retain as much information as I had hoped from the online lessons. As a result, in the second semester of flipping I incorporated a post-lesson, pre-class assignment and had the students present their solutions to each other. Examples of "structured notes," online lessons, and pre-class assignments will be presented, as well as feedback from student evaluations. (Received September 13, 2013)

1096-E1-1563 **Jean M. McGivney-Burelle*** (burelle@hartford.edu), **Larissa Schroeder**, **Mako Haruta**, **Fei Xue**, **John Williams** and **Ben Pollina**. *Flipping Calculus.*

In spring of 2013 we initiated our NSF-funded project, Flipping Calculus(DUE #1245059), at the University of Hartford. Over the past year, we have collaborated on developing materials for Calculus I including screencasts, short assessments, in-class problem sets and voting/discussion questions. In this presentation we will provide an overview of our course materials and discuss student and instructor perceptions of the benefits and challenges of flipping pedagogy. (Received September 16, 2013)

1096-E1-1597 **Robert Talbert*** (talbertr@gvsu.edu), Department of Mathematics, Grand Valley State University, 1 Campus Drive, Allendale, MI 49401. *"A different type of math": Addressing student difficulties with proof by flipping the transition-to-proof course.* Preliminary report.

To prepare for proof-based courses, many Mathematics majors take courses designed to teach the reading and writing of mathematical proofs, often called *transition-to-proof courses*. Students who complete such courses, it is hoped, will be able to focus on the content of proof-based mathematics courses and not on the process of proof-writing itself.

However, many studies of transition-to-proof courses show that this goal does not always materialize. Students encounter a variety of cognitive difficulties both during and following their proofs courses, but not many of which are actually related to mathematical content. Instead, difficulties arise from a persistent view of mathematics as computation, from a lack of self-regulated learning behaviors, and from an insufficient acquisition of professional norms.

In this talk, we will examine the redesign of a transition-to-proofs course using the flipped classroom model in an effort to address intentionally these sources of difficulty students encounter. We will examine the instructional design, resources, and finally the student reactions to their experience in the course and map out plans for future work. (Received September 16, 2013)

1096-E1-1682 **Joseph Sheridan*** (sheridanj@trinitydc.edu) and **Kerry M. Luse** (lusek@trinitydc.edu). *A Hybrid Flipped Classroom to Better Serve the Under-Resourced Student.* Preliminary report.

Introductory algebra courses are often filled with under-resourced students. These are students that have poor preparation for mathematics for a variety of reasons. The drop-out/failure rates for these students can be as high as 75%. As noted in various studies under-resourced students place a far higher value on personal one-on-one engagements than anything else. These students need the relationships established through the traditional lecture setting before they are open to learning. A completely flipped classroom would not be appropriate for our math sequence at Trinity.

When we redesigned our Introductory Algebra we added a one-credit student-centered supplemental laboratory in conjunction with Visual, Auditory and Kinesthetic styled classroom lectures. The lab is used to bolster the lecture and is designed as a flipped classroom. We have created a hybrid course combining the best parts of online systems, face-to-face interactions, and flipped classrooms that best serves our student population. The course redesign has improved student self-efficacy and in turn has helped our pass rates climb to 80% and our retention rates to 84%.

Our presentation will include a short video clip and a description of the labs. We will present data collected over several semesters. (Received September 16, 2013)

1096-E1-1735 **Marie P. Sheckels*** (msheckel@umw.edu), Department of Mathematics, University of Mary Washington, 1301 College Ave., Fredericksburg, VA 22401. *Lessons Learned: A First Attempt at Using a Flipped Classroom Model.*

This session will discuss a first attempt at designing and implementing a flipped classroom model in a mathematics content course for future elementary teachers. While the course started off well, difficulties were encountered during the semester. Although the design was not entirely successful, the professor and students alike learned lessons for future instruction. This session will describe some of the problems that were encountered, some considerations that would have been helpful, and the lessons that were learned with the hope of helping other instructors who may be anticipating utilizing this model of instruction in a mathematics class. (Received September 16, 2013)

1096-E1-1930 **William J Heuett*** (wheuett@marymount.edu), VA. *Experiences and Experiments in Implementing a Flipped Classroom Design in an Introductory Statistics Course.*

For two years I have worked to design and implement a flipped classroom design in an introductory statistics course. During that time, I conducted two experiments to test my methods. In the first experiment, two sections (70 students total) were taught using the flipped classroom design and one section (35 students total) was taught using a traditional lecture style. In the second experiment, three sections (105 students total) were taught each with an array of assessment methods aimed at assuring that students watch the video lectures outside of class and come prepared to do the in-class activities. I will discuss the results from both experiments, focusing on measures of student learning outcomes. I will also discuss some of the nuts and bolts involved and the technology that is available. (Received September 16, 2013)

1096-E1-1977 **Cassie Williams*** (willi5cl@jmu.edu), James Madison University, Harrisonburg, VA. *Flipping for the first time.* Preliminary report.

Many college students think that learning is achieved by coming to class and waiting while knowledge is poured into their brains. Conversely, many professors lament that their students do not spend enough time on mathematics outside of class time. To more actively involve students in the learning process, both in and out of class, I flipped my Calculus I course during the Fall 2013 semester. In this talk, I will share my experiences as a first-time flipper. In particular, I will explain the class structure I employed, discuss practical and technical considerations in the use of technology, activity design, and classroom management, describe the students' reactions, reflect on what worked, and share what should never be repeated. (Received September 17, 2013)

1096-E1-2003 **Joyati Debnath*** (jdebnath@winona.edu), Department of Mathematics and Statistics, Winona State University, Winona, MN 55987. *Idea of flipped classroom for Pre-calculus students.*

At the beginning it was not very clear to me how a flipped classroom could be an effective tool for the students to learn mathematics. I was not sure if I can actually implement this concept. After attending few sessions and listening to fellow mathematicians I decided to give it try in a PreCalculus course. This presentation will highlight the experiences gained and the lessons learned by both of us (students and myself). (Received September 17, 2013)

1096-E1-2115 **Bruce Carpenter*** (carpent@illinois.edu), 273 Altgeld Hall, 1409 W. Green St, Urbana, IL 61801, and **Faisal Whelpley** (faisal@makingmath.com), 41 E University Ave, Champaign, IL 61820. *Learning Math by Making Math.*

For over twenty years, the Calculus&Mathematica and NetMath programs at the University of Illinois have delivered high quality, innovative, computer-based mathematics instruction both face-to-face to on-campus students and online to students worldwide. Based on this experience, a new instructional design paradigm and new web-based tools for using an online version of Mathematica to teach mathematics at the undergraduate and high school levels will be presented. Dubbed Making Math, the system combines Constructionist learning ideas and Formative assessment to bring about a radically different approach to math education. The use of technology in the classroom redefines the traditional flow of information from instructor to students. Rather students are directly engaged with mathematics through experimentation and exploration with the guidance and feedback from instructor. (Received September 17, 2013)

1096-E1-2159 **Michael A Posner*** (michael.posner@villanova.edu). *A Flipped Class: The Challenges and Benefits of Changing the Classroom Dynamic to be Consistent with Cognitive Learning Theories and Focus on Student-Centered Learning.*

The flipped/inverted classroom is a popular technique that has shifted the landscape of education and changed faculty from ‘sage on the stage’ to the ‘guide on the side,’ where they become learning facilitators who employ active-learning techniques and fully leverage the power of technology in and out of the classroom. In this pedagogical innovation, instructional materials are provided for students via a number of modalities and students are required to become proficient in this material before the class meeting times. Class time is spent on “high-touch” experiences and individual attention fosters differentiated instruction and caters to heterogeneous learning styles and student experiences. I will discuss my experiences of two years of flipping an introductory statistical methods course (for quantitative majors), why cognitive learning theories and my experiences in educational research have convinced me of the value of this method, the two most important things to know if you want to flip a course or a module of your course, and other benefits and challenges from flipping. (Received September 17, 2013)

1096-E1-2170 **Melissa M. Tolley*** (m.tolley@wingate.edu), Charlotte, NC 28212. *A First Attempt at Flipping.* Preliminary report.

As a first year instructor we face challenges on teaching styles, especially with new techniques, such as classroom flipping being introduced. In this paper I discuss the struggles (and successes) of flipping at a small, liberal arts school while revieling strategies that worked for my class, and how teaching was morphed into an in-between style. (Received September 17, 2013)

1096-E1-2178 **Steven Pon*** (steven.pon@uconn.edu), **Fabiana Cardetti** and **Konstantina Christodoulopoulou**. *Flipped versus Traditional: Measuring Success through Performance and Perceptions.*

Classroom flipping has gained prominence in recent years and holds promise as a means of improving the classroom experience and bolstering student learning; however, there is still limited evidence as to the effects of flipping the classroom on student performance, especially at the undergraduate level. In this talk we will present the results of a study we conducted in an undergraduate introductory calculus classroom, temporarily flipping two sections of the class and comparing student performance from those two sections with student performance across five other sections of the same course. We also collected survey data on student perceptions of the flipped classroom experience and looked for correlations between student perceptions and student performance in the flipped classroom model. In addition, we will share details of our implementation of this teaching method and the lessons we have learned. (Received September 17, 2013)

1096-E1-2280 **Alex Capaldi*** (alex.capaldi@valpo.edu), 1900 Chapel Dr., Valparaiso, IN 46383, and **Melissa Desjarlais** (melissa.desjarais@valpo.edu), 1900 Chapel Dr., Valparaiso, IN 46383. *A Faculty Learning Community on Flipped Classrooms at Valparaiso University.*

This year at Valparaiso University, a flipped classroom Faculty Learning Community (FLC) is underway with a plurality of its membership being mathematicians and 80% of the participants currently flipping their classrooms. An FLC is an interdisciplinary group of faculty who engage in an active, collaborative year-long program designed to enhance teaching and learning and with an emphasis on building community. The aim of this presentation is to discuss how the FLC is organized, what it has and hopes to accomplish (such as methods of assessing the effectiveness of flipped classrooms and producing a ”start-up” guide for faculty wanting to flip a course) and to share anecdotes. (Received September 17, 2013)

1096-E1-2469 **James S Rolf*** (jim.rolf@yale.edu), Department of Mathematics, Yale University, 10 Hillhouse Avenue, New Haven, CT 06511, and **Yu-Wen Hsu**, **Matthew Croasmun** (matthew.croasmun@yale.edu) and **Jennifer Frederick**. *Implementing the ICE Framework in a Hybrid Mathematics Classroom.* Preliminary report.

We report on the deconstruction of a traditional Calculus lecture into three components that blend online and face-to-face instruction. Our "Inform, Confirm, Extend" (ICE) framework incorporates pre-class videos to deliver basic Information, assigns pre-class online prep problems to Confirm student (and instructor) understanding, and Extends student understanding with in-class peer instruction. We describe the challenges and lessons learned during the development and implementation phases of this work, as well as outline a controlled experiment to assess the project outcomes. In particular, we will describe obstacles in this process as well as beneficial institutional collaborations. Lastly we will discuss planned future steps to transfer this approach to other instructors and to evaluate the effectiveness of scaling this approach to larger numbers of students. (Received September 17, 2013)

1096-E1-2474 **Edwin P Herman*** (eherman@uwsp.edu), 2001 Fourth Avenue, Department of Mathematical Sciences, University of Wisconsin-Stevens Point, Stevens Point, WI 54481. *More than just a video – flipping the classroom to improve student learning.* Preliminary report.

I decided to flip my spring 2013 section of Calculus I to increase the amount of class time for student work. I was already using half of my class time for students to solve problems; by placing part of the lecture material in a video I figured that students could work and present more in class and better grasp the material. Unfortunately, this did not occur – in spite of the extra time, students did not present more board work, and performance on exams did not seem better than previous classes. A survey at the end of the semester indicated one possible reason: less than 30% of the students reported that they watched most of the videos.

Those who did watch the videos reported that they were quite helpful, so I decided to try again for my summer section. This time I used multiple short videos each day instead of one longer one. I also modified the order of topics a little, introducing some concepts much earlier than the textbook. To encourage students to watch the videos more often I added a daily homework component to the course. As a result of these changes, the "watch rate" reported by students increased dramatically, with student feedback still extremely positive. More importantly, student performance (both board work and exam work) improved on many topics. (Received September 17, 2013)

1096-E1-2485 **Ellie Kennedy*** (ellie.kennedy@nau.edu). *A Flipped Classroom Study in Second and Third Semester Calculus.*

In Spring 2013, a study was done with 175 Second Semester Calculus students. Half of these students were taught via direct instruction and half were taught using a flipped classroom approach, where videos were utilized as lectures and classroom time was devoted to students working on problems in small groups and asking questions. Through survey data (MSLQ and SALG-M) and exam scores, the two different teaching methods were compared. In particular, learning gains, student perception of the effectiveness of the instructional approach, and student attitude towards learning mathematics were analyzed. In Fall 2014, a study was done with 140 Third Semester Calculus students. All of the students were taught using a flipped classroom approach. Learning gains, student perception of the effectiveness of the instructional approach, and student attitude towards learning mathematics were analyzed. This talk will discuss the details of the instructional methods and the results of the data analysis. (Received September 17, 2013)

1096-E1-2499 **J Alfredo Jimenez*** (jaj4@psu.edu), 76 University Drive, Hazleton, PA 18202. *Flipping the Classroom in a Calculus I Class via Online Learning Modules.* Preliminary report.

I would like to present a series of three learning modules related with the approximation of area, and volume of solids of revolution, that I use in my calculus I class to implement the ideas of a flipped classroom. I have used these modules for a year, and the overall response by the students has been positive. Students find them convenient as they can work at their own pace, and easy to understand. I find that students can learn on their own some basic concepts and notation such as partition of an interval, left- and right-endpoints, midpoint, left-, right-, and midpoint rectangular approximations. As a byproduct, I use class time to integrate knowledge and lead to the abstract definition of a definite integral. In addition, students develop a better idea of how to set up Riemann sums. (Received September 17, 2013)

1096-E1-2670 **Nathan P Clements*** (clementsuwyo@gmail.com). *Journey Into Flipping the Calculus I Classroom.* Preliminary report.

Though I have been assigning online videos as homework for several semesters, only recently did I start using them to replace direct instruction. This presentation will discuss my journey into flipping my classroom, including my initial reluctance, what finally forced me into it, and how my concerns were resolved.

Replacing instruction with videos gave more class time to the students to practice problems. The conversations during these sessions quickly showed me the understanding level of my students. In the traditional approach, I wouldn't discover my weaker students were until after the first exam. Now I know them by the end of the 2nd week of class.

I can easily defer the procedural skills (such as use of the power rule) to videos. Still many topics I feel I must teach directly. Only about half the class time is spent practicing problems, with the other half in direct instruction. This is still a work in progress. (Received September 17, 2013)

1096-E1-2684 **Jeremy F. Strayer***, Department of Mathematical Sciences, MTSU Box 34, Middle Tennessee State University, Murfreesboro, TN 37132. *Designing the classroom flip for learner-centered mathematics instruction.*

As education moves further into the information age, instructors' roles are profoundly changing. Most pertinent to the classroom flip model is a move away from the instructor as the source of information in a course. Completing tasks that help students learn to think with readily available information requires that teachers make space for students to communicate their thinking and critique the reasoning of others during class. This takes a great deal of time, and time is a precious commodity in the classroom. With agreed-upon lists of content that specific courses are required to help students learn, most instructors are unwilling not to cover the topics required by the curriculum for a course. In this context, the classroom flip provides a viable instructional model for instructors who seek to teach in a student-centered way without sacrificing course content. This paper outlines both universal and situational principles for designing flipped instruction in a mathematics classroom. These principles are built from research in flipped classrooms and theories of learning and instructional design that support student-centered learning. The principles highlight the importance of using a consistent instructional approach when designing and implementing flip instruction. (Received September 17, 2013)

History of Mathematical Communities

1096-E3-96 **Penny H. Dunham*** (pdunham@muhlenberg.edu), 2400 Chew St., Mathematics and Computer Science Dept., Allentown, PA 18104. *The NCTM Oral History Project: Documenting Community Memory of Mathematics Education in the United States.*

In 1994, the National Council of Teachers of Mathematics (NCTM) established the Task Force on the History of Mathematics Education. Its principal charge was to consider how NCTM could best document the most important events in mathematics education in the latter half of the 20th century. Recommendations included expanding the permanent archives, publishing two books (a formal history and a reader of critical documents), and instituting an Oral History Project (OHP). In 1997-98, a committee created guidelines for the OHP, and in 2001 a new task force began planning, collecting, and processing oral history interviews to preserve the stories and experiences of leaders in the mathematics education community. As a member of that task force, I will describe how we organized and executed the OHP and will provide information on funding, interviewee selection, and interview preparation. Finally, I will address the outcomes of the OHP and the ways we processed, disseminated, and archived the oral histories. (Received July 26, 2013)

1096-E3-221 **Sarah J Greenwald*** (greenwaldsj@appstate.edu), 326 Walker Hall, 121 Bodenheimer Drive, Boone, NC 28608. *40+ Years of the AWM (Association for Women in Mathematics): The History of AWM and the AWM Archives.*

The Association for Women in Mathematics (AWM) is a non-profit organization that supports and promotes female students, teachers and researchers. Even though the very early beginnings of the AWM are connected to gatherings in Boston in the late 1960s, the organization officially formed out of the 1971 Joint Mathematics Meetings in Atlantic City. Today, with more than 3000 members (women and men), the AWM represents a broad spectrum of the mathematical community - from the United States and around the world.

While the AWM was celebrating its 40th anniversary in 2011, I was beginning to research the history of the organization through the lens of the AWM Newsletter archives. Past President Jean Taylor graciously donated the funds that enabled the AWM to make the archives public and I have been working on a searchable database for them. The volumes provide fascinating insight into the organization and a wealth of information about women in mathematics in general over the last 40 plus years. In this talk, I will discuss the history of the organization, focusing on how the AWM formed and has continued to adapt in response to societal needs and concerns as well as how the organization in turn impacted both mathematics and the mathematical community. (Received August 20, 2013)

1096-E3-484 **Della Dumbaugh*** (ddumbaugh@richmond.edu), Dept. of Mathematics, University of Richmond, Richmond, VA 23173. *Time and Place: Sustaining the American Mathematical Community.* Preliminary report.

The "common interest" of mathematics in the last quarter of the nineteenth century contributed to the emergence of an American mathematical community. What "standards and traditions" evolved as mathematicians strengthened this community in the opening decades of the twentieth century? Using the private exchanges of Leonard Dickson and Oswald Veblen, this talk explores some of the issues and events that shaped this phase of growth in the American mathematical community. (Received September 04, 2013)

1096-E3-532 **Emelie A. Kenney*** (kenney@siena.edu), Department of Mathematics, Siena College, 515 Loudon Road, Loudonville, NY 12211. *Origins and National Character of the Polish School of Mathematics in pre-WWII Lwow, Warszawa, and Krakow.* Preliminary report.

What do we mean by a 'school' of mathematics? What do we mean by 'Polish mathematics'? What was the genesis of the Polish School? Who was active in it, what did they do, and where did they do it? We attempt to answer these questions, in addition to presenting material on the role that universities, journals, societies, meetings, and famous visitors to Polish mathematics centers played in the growth of that school, a school that was intentionally created specifically as a school of Polish mathematics. We conclude with a post-script on the extraordinary underground community of mathematicians (and others) during World War II, whose clandestine activities made it possible, even though so much was lost, to rebuild a thriving intellectual life after the war. (Received September 05, 2013)

1096-E3-1253 **Satish C Bhatnagar*** (bhatnaga@unlv.nevada.edu). *History of Mathematics in Punjab.*

This paper is about my ongoing researches in a regional history of mathematics, mathematicians, mathematics curriculum and institutions in Punjab, the most well-known state of India. However, the reliable records are only available since 1849, when Punjab was annexed into British India. In 1947, nearly half of the state was carved out of India into a new nation of Pakistan. The paper focuses on Punjab of present India. It traces mathematical history, for example, from one or two colleges in late 19th century to nearly a dozen universities and 500 colleges presently. However, homegrown mathematics research of the caliber, say, as done in the top 20 math departments in the US, has a long way to go. Some political and economic factors are also elaborated. (Received September 14, 2013)

1096-E3-1382 **Glen R Van Brummelen*** (gvb@questu.ca), 3200 University Boulevard, Squamish, BC V8B 0N8, Canada. *Where Zijes Went: The Travels of Astronomical Tables in Medieval Islam.* Preliminary report.

Astronomical tables, as documents intended for practical use rather than scientific insight, often leave distinct traces of their origins, and so can provide unique insights on the spread of ideas through communities. In medieval Islam, the table tradition arrived from India through Persian intermediaries in the 8th century. By the end of the 9th century, eastern Islam had seen a conversion to Ptolemaic methods, but these newer methods saw only limited play in the west (al-Andalus and the Maghrib), which developed from this point onward largely separated from the east. Bursts of activity and innovation occurred in the east from the late 10th century onward, spurred by the founding of several observatories and associated centers of research. (Received September 15, 2013)

1096-E3-1487 **Lawrence D'Antonio*** (ldant@ramapo.edu), 24 Meadoway, DOBBS FERRY, NY 10522. *The Mathematics Class at the Berlin Academy in the 18th Century.* Preliminary report.

In the 18th century professional academies played a significant role in supporting research in mathematics and the sciences. In this talk we will examine the impact of the Berlin Academy of Science. A distinguishing feature of the Berlin Academy was its organization into discipline based classes. The mathematics and philosophy classes were of particular importance in the 18th century. Euler, Lambert and Lagrange were the three most illustrious resident mathematicians of the Academy. We will look at the history of the Academy from its founding, to its revitalization under Frederick the Great, through the leadership of Maupertuis and Euler, ending with the twenty year term of Lagrange as director of the mathematics class. We will also discuss the prize competitions regularly sponsored by the Academy. (Received September 15, 2013)

1096-E3-1586 **James J. Tattersall*** (tat@providence.edu), Department of Mathematics, Providence College, Providence, RI 02918, and **Kenneth A. Ross**. *An incident in planning national meetings for the mathematical community.* Preliminary report.

We discuss the planning and subsequent undoing of the joint mathematics meeting scheduled for Miami in January 1970. (Received September 16, 2013)

1096-E3-2220 **Dominic Klyve*** (klyved@cwu.edu). *The "Partly-Visible" College: Euler and the mathematical community in the 18th century.*

The Eighteenth Century was an important time of transition, as the field of mathematics was growing rapidly, but the modern university hadn't really developed. Furthermore, mathematicians' understanding of the role of research journals was still evolving. Much mathematics during this period was developed and disseminated not in published form, but in letters. In this talk, we shall use Leonhard Euler's correspondence as a lens through which to view mathematical collaboration and information exchange during the 18th Century. (Received September 17, 2013)

1096-E3-2751 **Kat Rands*** (krands@elon.edu). *Queering Mathematical History: A Queer Genealogy of the Mathematical Community, Bourbaki.*

This paper suggests a queer history approach to mathematical history and uses it to analyze one mathematical community, Bourbaki. Firestone critiques the way history is often told as a series of "snapshots." Examples of both mathematics and LGBT history from the snapshot perspective abound—for example, sidebar boxes in mathematics textbooks that snapshot a famous mathematician and timelines of significant LGBT events. Mendick critiques the snapshot/progressive view of history of mathematics education as defining a linear and teleological relationship between the past, present, and future in a way that contrains the questions asked and actions taken. In contrast, Mendick proposes Foucauldian genealogical approaches, which look for dissonance rather than continuity, difference rather than identity, and contingency rather than inevitability. Bronski makes the surprising claim that LGBT history does not exist. This signifies on the one hand that the queer is central to history itself, so there is no "separate" LGBT history, and at the same time that the queer has been so suppressed as to be erased in the past. This paper examines the mathematical community Bourbaki through a queer genealogical lens. (Received September 18, 2013)

Innovative and Effective Ways to Teach Linear Algebra

1096-F1-592 **Alexander Louis Garron*** (alexander@sandboxgeometry.com). *On The Heliocentric Circular Mechanical Energy Curves of Galileo.*

Galileo, born 7 years before and dying 12 years after Kepler, was well aware of Kepler's solution concerning complexity about orbit parameters of our sister planet Mars. He refuted till his death, Keplerian elliptical planetary motion as much too complicated. Though a heliocentric advocate as was Kepler, he held that natural curves of an orbit must be circular. This paper explores Galileo's concept of circular heliocentric planetary motion. I develop a standard model using two plane geometry curves, a unit circle and its construct unit parabola, creating a plane geometry function needed to measure g-field energy curves. It turns out that g-field inverse square energy curves are spherical, can be constructed using NASA sourced observation parameters, build a standard model space and time square, once constructed provide analytics for orbit momentum around our sun and across the g-field time curve, all within reach of STEM HS math. Both curves, his circles and Kepler's ellipse, can be used to explain gravity field orbit mechanics. (Received September 07, 2013)

1096-F1-605 **Andrew J. Simoson*** (ajsimoso@king.edu), King University, Mathematics Department, 1350 King College Road, Bristol, TN 37620. *Bilbo and the Last Moon of Autumn.*

In J.R.R. Tolkien's *The Hobbit*, Bilbo must reach the Lonely Mountain in the waning light on the first day of the last moon of autumn; upon hearing such news, the chief dwarf of this expedition comments that no-one knows how to determine such dates anymore. However with a simple motion model of the earth, moon, and sun, and a little linear algebra, we show a way to determine years in advance any given lunar holiday. In particular, we find two rules, modulo some technicalities due to the Gregorian leap year phenomenon: Rule 1: A new moon will occur on the same date as it did 19 years ago (a rule used in the Julian calendar to determine the date of Easter), and Rule 2: A new moon will occur two days later than it did 160 years ago. (Received September 07, 2013)

1096-F1-656 **Itai Seggev*** (is+research@cs.hmc.edu), Wolfram Research, Inc., 2000 Trade Center Dr, Champaign, IL 61820. *Frame Construction in Linear Algebra: Frenet-Serret as Modified Gram-Schmidt.*

The existence and computation of the Frenet-Serret frame is commonly viewed as a topic in vector calculus, specific to 2- or 3-dimensional Euclidean space. While it is rooted in differential geometry, the construction of the frame is better thought of as a modified Gram-Schmidt process applied to the tangent field and its derivatives. It thus can be applied to curves in any inner-product space and fits naturally into a course on linear algebra. The frame provides an immediate application of and visualization for Gram-Schmidt. Additional concepts, such as orientation, the perpendicular space, and basis completion can be easily added or avoided by careful selection of examples. By using functionality available in recent versions of Mathematica, this topic can be explored conceptually and with a minimum focus on computation (if so desired). (Received September 08, 2013)

1096-F1-783 **Tim Chartier*** (tichartier@davidson.edu), P.O. Box 6908, Department of Mathematics, Davidson, NC 28035. *From March Madnesss to MATHness with linear algebra.*

Every year, people across the United States predict how the field of 64 or more teams will play in the Division I NCAA Men's Basketball Tournament by filling out a tournament bracket for the postseason play. This talk discusses how to use linear algebra algorithms used by the Bowl Championship Series, the organization that determines which college football teams are invited to which bowl games, to create brackets for March Madness. In particular, this talk focuses on how to make this a classroom project or activity in math classes for math majors or non-majors. (Received September 10, 2013)

1096-F1-1192 **Rosemary Carroll Farley*** (rosemary.farley@manhattan.edu), Mathematics Department, Bronx, NY 10471. *Student Projects to Visualize Iteration Patterns of Matrices with Complex Eigenvalues.*

This presentation will demonstrate how the computer algebra system Maple was used by undergraduate student researchers to create visualizations of the iterates of a point under the action of a 2 x 2 matrix with complex eigenvalues. When the iterates fell on an ellipse the students found an equation of the ellipse and created an animation to explain the rotation and the scaling involved. The results of these student projects have been used in subsequent courses to clarify this material. The simple four step method used to create such animations will be explained. The value of such projects in terms of linear algebra learned will be discussed. (Received September 13, 2013)

1096-F1-1536 **Gilbert Strang***, Dept. of Mathematics, MIT, Cambridge, MA 02139. *Row rank equals column rank: Three good proofs.*

This is the first big theorem in linear algebra: the row space and column space have the same dimension. Here are three approaches and there are more—we will reveal our favorite. We hope the audience has favorites too, and experience with presentation to students.

1. Reduce the matrix to echelon form and compute dimensions.
2. Independent $x_1, \ldots, x_r$ in the row space give independent $Ax_1, \ldots, Ax_r$ in the column space.
3. If the rows of W are a basis for the row space of A, then $A = UW = (m \text{ by } r)\ (r \text{ by } n)$. Then the r columns of U span the column space of A.

(Received September 16, 2013)

1096-F1-1538 **Gilbert Strang***, Dept. of Mathematics, MIT, Cambridge, MA 02139. *Analogies between matrix equations and linear differential equations.*

This talk is pedagogical. It is about connecting two basic courses —differential equations and linear algebra. Students who don't have much time (engineers, scientists, economics majors, . . .) still need to see both.

One important connection is the structure of solutions to all linear equations: "particular solution" plus all "nullspace solutions".

Another link comes from $AA^{-1} = I$. The columns of A^{-1} are like the solutions to differential equations (when the right hand side is a delta function).

Finally: A second order equation has a 2-dimensional nullspace (which explains why there are 2 initial conditions). But what is the "row space" of a differential operator with no rows? (Received September 16, 2013)

1096-F1-1579 **Robert Talbert*** (talbertr@gvsu.edu), Department of Mathematics, 1 Campus Drive, Grand Valley State University, Allendale, MI 49401. *Peer instruction in linear algebra.* Preliminary report.

Peer instruction is a method of teaching pioneered by Eric Mazur of the Harvard University Physics Department to improve students' conceptual understanding of physics. For over 20 years, peer instruction has been at the center of a large body of SoTL literature showing its effectiveness in improving student learning in physics and other STEM disciplines across a variety of institutional settings. In this talk, we describe the application of peer instruction in linear algebra. We will discuss the method of peer instruction in general and its potential benefits in linear algebra, and then look at a peer instruction-centered redesign of a linear algebra course. Finally we examine some sample data from student work along with future plans for further implementation of peer instruction. (Received September 16, 2013)

1096-F1-2035 **Don Spickler*** (despickler@salisbury.edu), Henson Science Hall 132E, Salisbury University, 1101 Camden Ave., Salisbury, MD 21801. *Using Classical Cryptography and Cryptanalysis as an Enrichment Exercise in a First Course in Linear Algebra.*

The Hill cipher is a block cipher that was developed by Lester Hill in 1929. Although it does not seem to have been used much at the time and by today's standards is not a secure cryptographic system it does provide a very nice application of matrix arithmetic, inversion, and the properties of linear transformations. Furthermore, it is accessible to beginning mathematics students and extends the classroom material, usually done over the real number system, to the modular case in a natural and concrete way. In this talk we will go through an enrichment exercise on the Hill cipher that is suitable for a beginning course in linear algebra. The calculations will be facilitated by the software package Linear ME (Maxima Edition), a linear algebra exploration tool developed by faculty and students at Salisbury University. (Received September 17, 2013)

1096-F1-2148 **John Hannah** and **Sepideh Stewart***, 601 Elm Avenue, Norman, OK 73019, and **Michael Thomas**. *Teaching Linear Algebra with Clickers in three Worlds of Embodied, Symbolic and Formal Mathematical Thinking.*

Linear algebra is one of the first advanced mathematics courses that students encounter at university. Research shows that although many students find the calculation side of the course, specially manipulating matrices relatively straightforward, they lack the theoretical understanding of basic linear algebra concepts. In this research we have employed Tall's framework of three worlds of embodied, symbolic and formal mathematical thinking to analyse students' thinking processes and suggest ways forward in teaching linear algebra. As part of this study, we integrated clickers into teaching two groups of linear algebra students to investigate whether the order (formal definitions and theorems, symbolic representations, pictures and geometry) in which the main linear algebra concepts are presented has an impact on students' learning. (Received September 17, 2013)

1096-F1-2267 **Teresa D Magnus*** (tmagnus@rivier.edu), Dept. of Mathematics & Computer Science, Rivier University, 420 S. Main Street, Nashua, NH 03060. *Putting Together the Puzzle: Understanding Linear Independence, Spanning, and Bases via Group Exploration.*

The key concepts of linear independence and spanning sets are often challenging for students in Linear Algebra. In fact, since they often occur together in the course timeline, students tend to blend them together and need extra guidance in recognizing the distinct characteristics associated with each. The presenter will share a two-part group activity used in her linear algebra class to encourage students to delve deeper into these important topics, first by examining examples to determine when shortcut procedures are possible and then by using puzzle cards to identify under what circumstances one can claim a set of vectors is linearly independent (or dependent) and when it spans (or does not) span $\mathbb{R}^n$. (Received September 17, 2013)

1096-F1-2326 **Christina M. Selby*** (selby@rose-hulman.edu). *"Where Am I?" A Change of Basis Project.*

Linear algebra students are typically introduced to the problem of switching from one coordinate system to another in an abstract way. Often two bases for a vector space are provided and students are taught how to determine a transition matrix to be used for changing coordinates. If students are successful in memorizing this mathematical process, then they are successful at completing such problems. However, students may not be exposed to a physical interpretation of what is accomplished through changing coordinate systems or why one may desire to do so. Based on personal NASA industry experience, a linear algebra project has been developed which involves physical interpretation of changing bases. A space satellite with a payload is modeled with many coordinate systems. Each onboard instrument has at least one associated coordinate system, as does the spacecraft itself. A point in space must be interpreted relative to these different coordinate systems in order to accurately analyze data that is collected. The physical nature of this project provides motivation for the change of basis topic in linear algebra, and also provides students a better intuition of what it means to change basis. (Received September 17, 2013)

1096-F1-2586 **Feryal Alayont*** (alayontf@gvsu.edu), GVSU Mathematics Department, 1 Campus Dr., Allendale, MI 49401. *Preparing students for linear algebra concepts with pre-class work.*

When trying to understand the abstract concepts of linear algebra, such as vector spaces, linear independence and span, examples and geometric perspective can be useful tools for students. However, class time is too limited to be able to offer these tools at all times. Moving some of the example creation, conjecturing, and geometric visualization to pre-class activities that students complete before coming to class provides time in the classroom for building deeper understanding from the students' own examples and results. In this talk, I will describe my format for these pre-class activities, and student responses to the activities. (Received September 17, 2013)

1096-F1-2650 **Steve Hilbert*** (hilbert@ithaca.edu), Department of Mathematics, Ithaca College, Ithaca, NY 14850. *Using March Madness in the First Linear Algebra Course.* Preliminary report.

I used the NCAA basketball tournament (March Madness)for a project in my linear algebra course. Using the Colley model gave a realistic reason for using matrix algebra to simplify manipulating realitively large matrices. The class built models for the Big East tournament from scratch and then used the UDEMY web site of Tim Chartier to make out their NCAA brackets. Using the tournament gave the class a problem with a non-negotiable deadline and feedback about how well their models performed. There were over 8 million entries in the ESPN game and students received bonus points for finishing in the top 50%,40%,30%,20%,10% and the best in the class. This topic also involved a non typical application of linear algebra that interested many students. (Received September 17, 2013)

1096-F1-2709 **James D. Factor*** (james.factor@alverno.edu) and **Susan Pustejovsky**. *Transforming Linear Algebra with GeoGebra.* Preliminary report.

Linear Algebra is a course where the main concepts have algebraic and graphical facets, providing a perfect setting to foster student mathematical growth by encouraging the integration of algebraic and graphical understandings of central ideas. GeoGebra is a dynamic mathematics tool, allowing the creation of interactive learning modules so a student can explore and learn Linear Algebra ideas in a setting in which fluency in moving between algebraic and graphical representations is encouraged.

This talk will present a package from a sequence of three GeoGebra applet packages centered on vectors and their representations, vector operations, and linear combinations of vectors. The sequence of learning module packages begins at the foundational level and moves to intermediate level ideas, finally to a more advanced level, each level building on the previous one(s). Each applet package includes a 2D/3D interactive applet, instructional support, and applications.

The work is part of a larger project entitled "Transforming Linear Algebra Education with GeoGebra Applets" (NSF DUE-1141045).

Our goal is to support students so they can easily use geometric, analytic, and numeric representations in the process of understanding and solving linear algebra problems. (Received September 18, 2013)

Instructional Approaches to Increase Awareness of the Societal Value of Mathematics

1096-F5-453 **Yevgeniy V Galperin***, East Stroudsburg University, Department of Mathematics, 200 Prospect St., East Stroudsburg, PA 18301. *College Algebra or Economics of Being Green.*

We discuss some of the challenges faced by instructors who teach general education courses in college algebra and ways of addressing these challenges by means of incorporating materials and projects related to environmental awareness, while at the same time helping students to prepare for future careers. (Received September 03, 2013)

1096-F5-662 **Maritza M. Branker*** (mbranker@niagara.edu), Department of Mathematics, Niagara University, NY. *Building a capstone course on the theme of the relevance of mathematics to society.*

This talk will outline the successful capstone course at Niagara University catering to mathematics majors and pre-service teachers with a concentration in mathematics. The theme of the course is the relevance of mathematics to society and the topics covered include game theory, linear programming and the theory of computation. The underlying goal of the course is to enable students to appreciate the pervasive nature of mathematics and gain a better understanding of the vast scope of mathematics as a discipline. (Received September 08, 2013)

1096-F5-817 **Olivia M. Carducci*** (ocarducci@esu.edu). *A Service-Learning Approach to Mathematical Modeling.*

Each spring I teach a course in mathematical modeling. For the last six years, the course has culminated in a service-learning project. The projects have included proposing population models to the Lehigh Valley Planning Commission, estimating the CO_2 emitted by cars traveling to and from campus for the University sustainability committee, developing a complete life-cycle cost model for gas fracking for the Pocono Environmental Education Center (PEEC), and developing complete life-cycle cost models for commercial wind and solar electricity generation for PEEC. Each project expands the students' appreciation for the value of mathematics in addressing community issues. In this talk, I will describe how I organize the course with special attention to how I organize the service-learning project. I will include information on how I identify appropriate service-learning projects and how I evaluate the impact the project has on the students. I will allow the students to speak for themselves through their comments in their required reflection papers. (Received September 10, 2013)

1096-F5-1090 **Alexandra Seceleanu*** (aseceleanu@unl.edu) and **Kathryn (Katie) Haymaker**. *Math in the City: connecting the classroom to the local community through mathematical modeling.*

Math in the City is an interdisciplinary course developed at the University of Nebraska-Lincoln, in which students engage in a hands-on learning experience. Using mathematical modeling, the students try to understand and address current major societal issues of local and national interest. The course is run in collaboration with local businesses, research centers and government organizations that provide data and act as consultants throughout the course, thus creating strong connections between academia and industry, while engaging students in a learning and discovery process.

The talk will evaluate the benefits of this capstone course for the students and local organizations involved, based on the presenter's experience in teaching the course in the Fall of 2013. This offering of the course focused on modeling the availability of fresh water resources in south-east Nebraska as a hot topic of interest under recurring drought conditions, using mathematical models based on ordinary differential equations. We shall explain how, in the words of a student, "Math in the City made you think. A lot. " (Received September 12, 2013)

1096-F5-1092 **Victor I Piercey*** (piercev1@ferris.edu), Ferris State University, Department of Mathematics, 820 Campus Drive ASC 2021, Big Rapids, MI 49307. *Supporting Quantitative Literacy with Service-Learning: The Pitfalls and the Promise.* Preliminary report.

Service-learning, the achievement of learning outcomes through the performance of an aligned community service project, has the potential to involve students in mathematical activities that can impact the lives of others. I will discuss 5 service learning projects that I incorporated into my quantitative literacy course along with successes and failures. (Received September 12, 2013)

1096-F5-1454 **A S ELKHADER*** (a.elkhader@northern.edu), 1200 S. Jay St., Department of Sciences and Mathematics, Aberdeen, SD 57401. *Examples on using material from a standard college algebra course to enhance students understanding of some social issues.*

This work will focus on how the instructor used standard topics of a college algebra course to enhance students' awareness of relevant social issues. Student, who worked in small groups, used mathematics to study the impact of modifying some parameters in a given mathematical model, analyze the social consequences of the modifications, and give a solution. Topics ranged from crime, marriage and divorce, immigration, education, access to medical care, employment and others are addressed. Numerous tools of assessment such classroom presentation, peer assessment, self- assessment, critiques, interviews, and others were used. (Received September 15, 2013)

1096-F5-1813 **Andrew J Miller*** (andrew.miller@belmont.edu), Dept of Mathematics and Computer Science, 1900 Belmont Blvd, Nashville, TN 37211. *Using Service-Learning to Connect a Quantitative Literacy Course to the Community.* Preliminary report.

Over the past several years, I have developed a course on *Quantitative Literacy and Consumer Finance* which examines quantitative, social, political, legal, and personal dimensions of consumer finance decisions, in particular the use of consumer credit. Twice when I have taught this course, I have included a service-learning component. In this report, I will discuss a study from the Fall 2010 course in which I used multiple measures, including an AAC&U VALUE rubric, to attempt to assess the impact of the service-learning projects on student achievement of course learning objectives and their effect on students' civic engagement. While the service-learning projects will be the focus of this report, I will also briefly comment on the other projects in the course and compare their effectiveness to that of the service-learning projects. (Received September 16, 2013)

1096-F5-2545 **Emilie Hogan*** (emilie.hogan@pnnl.gov), P.O. Box 999, MSIN K7-90, Richland, WA 99352, and **Gabriela Radu**. *Graph clustering for the high school classroom.* Preliminary report.

We ask students "Have you ever wondered how Facebook recommends friends? How do they know that a new person belongs to certain groups and may be your friend?" This is a topic that most, if not all, students can relate to. Two lesson plans, one for geometry and one for algebra, were developed based on research done by a teacher while completing a summer research internship. The research project was in graph clustering for model reduction in the power grid. Given time series data for phase angle in many generators the goal was to cluster generators based on similar phase angle behavior following a disturbance. We investigated graph clustering techniques such as Markov clustering, Markov chains, and normalizing and squaring each column of the adjacency matrix. This inspired lesson plans to illustrate concepts of graph clustering through geometry and algebra. In this talk we will quickly describe the research in the power grid, the lesson plans that were developed, and how the students responded to the lessons. (Received September 17, 2013)

Is Mathematics the Language of Science?

1096-G1-149 **James R Henderson*** (henderso@pitt.edu), 504 E. Main Street, Titusville, PA 16354. *The Mathematics of Quantum Mechanics: Making the Math Fit the Philosophy.*

Nowhere in the history of science is it clearer than in the case of the development of a mathematical formalism for quantum mechanics that mathematics is the language of the scientist, if not science. In the mid-1920s, Schrodinger and Heisenberg had different visions of quantum mechanical systems and chose different mathematical tools to describe them. As far as making predictions are concerned, the two formulations are of course equivalent, but it is interesting that each man adopted a mathematical model that matched his own vision of microscopic systems. Schrodinger believed his continuous, deterministic, time-dependent wave function gave a realistic picture of the evolution of quantum mechanical systems (his view would change considerably over time). Heisenberg had adopted what would in the 1950s come to be called the Copenhagen interpretation and denied systems evolved between measurements (indeed, to say even that much may be a category error); his matrix mechanics makes for a tight fit for this view. Though the stories of Schrodinger's evolving viewpoint and Heisenberg's defining the dominant interpretation are interesting in their own right, I will discuss how mathematics and philosophy developed organically in the exciting period at the outset of the quantum revolution. (Received August 09, 2013)

1096-G1-743 **Ronald E. Mickens*** (rmickens@cau.edu), Clark Atlanta University, Box 1744-, Physics Department, Atlanta, GA 30314. *Mathematics as an Emergent Feature of the Physical Universe.*

The elementary aspects of what came to be called "mathematics" were created to aid in the analysis, understanding, and prediction of those features of the physical universe of particular importance for human survival. Thus, mathematics had its genesis as a "help-aid" in exploration of human understanding and control over processes and events in the physical universe. We extend this argument to show that mathematics is not unreasonable effective as applied to the physical sciences; it is doing what it was constructed to do, i.e., function as a language, useful to the formation, analysis, and generalization of physical theories. The validity of this view does not preclude mathematics evolving (at a later time) into a separate discipline. A collection of essays on this subject is R.E. Mickens, (editor), "Mathematics and Science" (World Scientific, London, 1990) (Received September 09, 2013)

1096-G1-842 **Mate Szabo*** (mszabo@andrew.cmu.edu), PA. *The Roots Of Kalmár's Empiricism.*

According to Kalmár, mathematics always stems from empirical facts and its justification is, at least in part, an empirical question. The idea that mathematics has empirical origins appears already in his first philosophical paper, *The Development of Mathematical Rigor from Intuition to Axiomatic Method* from 1942. By that time Kalmár's view was influenced by Sándor Karácsony, a Hungarian linguist and educationist. Karácsony had his own version of a picture theory of language. In his view people represent everything by "inner pictures" and communication works in the following way: the aim of the speaker is to describe their "inner pictures" for the listener in a way that the listener can access the same "inner picture." In Karácsony's view, these "inner pictures" always stem from experience. For Kalmár, these "inner pictures," originated in our experiences, are indispensable for mathematics. We use the pictures to "read off" the properties of mathematical concepts, not only on an intuitive level but even on the most abstract, axiomatic level. In my talk I will to explain Kalmár's view in detail, touching upon Karácsony's influence. (Received September 10, 2013)

1096-G1-1195 **Carl E. Behrens*** (behrenscarl@yahoo.com). *Mathematics Is a Science in its Own Right.*
Wigner, like most physicists, viewed mathematics as a tool: as a means of exploring the physical world, of "discovering the laws of inanimate nature." But mathematicians since the middle of the 19th Century have made it clear that theirs is a discipline that is more than a tool, a language for decoding the laws of the inanimate universe. It is a science aimed at discovering the laws that govern the part of the physical universe that is comprised of the human mind. This talk will explore the characteristics of the science of mathematics, viewed from this mission. (Received September 13, 2013)

1096-G1-1414 **Jeff Buechner*** (buechner@rci.rutgers.edu), Conklin Hall 430 Dept Philosophy, 175 University Avenue, Newark, NJ 07102. *A New Look at Wigner's 'The Unreasonable Effectiveness of Mathematics in the Natural Sciences'.* Preliminary report.
There are several problems in the philosophy of mathematics that are intertwined in Wigner's elucidation of the unreasonable effectiveness of mathematics in the natural sciences. One problem is that of irrelevant inferences in mathematical proofs—that is, the question of when a proof of a mathematical theorem is genuine. Another problem is Kripke's skeptical problem for functionalist accounts of the mind, which gains traction from the way in which abstract objects are imperfectly realized in the real world. A third problem is that of the underdetermination of theory by data. That is, there are infinitely many incompatible functions each of which will (i) provide the same finite set of successful predictions and (ii) accord with the finite set of datapoints. This provides a reason for why the accuracy of a mathematical theory of the real world cannot be taken as a criterion of its truth—of reality and shows how the Kripke skeptical problem for functionalism is also a problem about the nature of physical reality. (Received September 15, 2013)

1096-G1-2034 **Ruggero Ferro*** (ruggero.ferro@univr.it), via Gabelli 57, 35121 Padova, PD, Italy. *No surprise for the effectiveness of mathematics in the natural sciences.*
There are views of mathematics for which it is obvious that pure and abstract mathematics has to be efficient in application. I claim that mathematics is a human attempt to tame the complication of multiplicity. Complication is the main limit to understanding. Thus we abstract, from the available data, those that we deem relevant. We also idealize (introducing aspects not present in the data) and generalize. These three mental operations lead us to build, on experienced data, a sufficiently manageable model of the situation (reality) differing from the situation analyzed, but approximating it well enough, even though introducing complexity. This is true not only of mathematics, but also of physics and of each of the other natural sciences: they develop theories describing models. Since models may become very complex, ingenuity is needed to understand them, making models object of scrutiny, comparisons and evaluations. It should be no surprise that advanced mathematical results are useful, because, since the beginning, they were meant to tame the complication of multiplicity, possibly even the kind of multiplicity present in a specific application. The presentation will try to justify the claims proposed and to answer more directly to the theme of this meeting. (Received September 17, 2013)

1096-G1-2359 **Horia I. Petrache*** (hpetrach@iupui.edu), 402 N. Blackford St., LD154, Physics, IUPUI, Indianapolis, IN 46202. *A group theory perspective of mathematical constructs in physics.* Preliminary report.
In physics, mathematical constructs such as Fourier transforms and complex numbers are regarded as useful tools: they are used because they work as needed to model physical systems and their behavior. But are these tools unique or even necessary? Can we do physics without Fourier transforms, or without trigonometric functions? To answer this odd question, one would need to try to reconstruct physics without these mathematical ingredients, a very impractical task to say the least. One could also reason that if these mathematical ingredients were not necessary, physics would have likely eliminated them already! It is suggested here that a more unified "rediscovery" of mathematical constructs can be useful to address the question of their uniqueness and necessity in physics. An example is provided based on an investigation of the differential operator within group theory at elementary level. The framework of group theory is appropriate at this point in time because physics theories fundamentally are group theories. By doing this, we do not discover new mathematical constructs or new properties. Rather, the purpose of this exercise is to see how a number of mathematical constructs appear as consequences of fundamental physics principles. (Received September 17, 2013)

Mathematics and Sports

1096-G5-50 **Stanley Rothman*** (stanley.rothman@quinnipiac.edu), 15 Stacy Ct., Cheshire, CT 06410, and **Faggella**. *Predicting a Team's Winning Percentage Using (Run Scored – Runs Allowed).*

Bill James developed the Pythagorean Theorem for Baseball, $W/L = (RS/RA)^2$. In this formula for an entire season, W = team wins, L = team loses, RS = runs scored by a team and RA = runs allowed by a team. Alternately, this formula says a team's winning percentage $W\% = 100*(RS)^2/[(RS)^2+(RA)^2]$. Using regression analysis, sabermetricians have shown that for a typical season the exponent will be close to 2. The research that follows was a joint effort between my student Kevin Faggella and me. We looked at the linear equation $W\% = m*(RS\text{-}RA) + b$. Using regression analysis, we showed that for any season in Major League Baseball (MLB), $m = \Sigma\ [(RS–RA)*W\%]/\Sigma(RS - RA)^2$ and $b = .50$. This same formula also works for the other two major professional sports leagues, the NFL and the NBA. The strong positive correlation between each year's $\Sigma[(RS - RA)*W\%]$ and each year's $\Sigma(RS - RA)^2$ allowed us to replace m by an approximating constant. For MLB, $W\% = .000683*(RS\text{-}RA) + .50$, for the NFL $W\% = .001538*(PS\text{-}PA) + .50$ and for the NBA, $W\% = .000364*(PS\text{-}PA) + .50$. PS is the season's points scored by a team and PA is the season's points allowed by a team. We found a strong positive correlation in each sport between the exponent in the Pythagorean Theorem and the slope m. (Received June 16, 2013)

1096-G5-82 **Diana Cheng*** (dcheng@towson.edu), Towson University, 8000 York Road, Towson, MD 21286, and **Tetyana Berezovski**. *Ice Math: Related Rates and Pairs Figure Skating.*

In light of the upcoming Winter Olympic Games in February 2014, a mathematical modeling problem is presented in the context of pairs figure skating. Prospective high school teachers used related rates to solve a problem that involves differentiation, the Pythagorean Theorem, and trigonometric equations relevant to a pairs skating element, the death spiral. To complete the death spiral, the man pivots in a small circle on the ice while the lady glides in a concentric circle with a larger radius around the man. Students were asked to find the instantaneous rate of change of the man's height while performing the death spiral, as well as the relationship between the man's height and the angle of inclination, formed by the lady's blade and the ice surface. Students' work is analyzed and discussed. (Received July 15, 2013)

1096-G5-414 **Eric B. Kahn*** (ekahn@bloomu.edu), 222 Ben Franklin Hall, Dept. Mathematics, Comp. Sci. & Stat., Bloomsburg University, Bloomsburg, PA 17815, and **Tricia M. Brown**. *American Football and an Unexpected Introduction into Upper Level Mathematics.*

Guiding undergraduate mathematics majors through the transition from calculation based courses to proof based ones is arduous for the instructor as well as frustrating for the student. In this talk, we will discuss how an application of concepts from abstract algebra and enumerative combinatorics to American football can ease these tensions. First focusing on the rules of the game and how they can be used to define an equivalence relation, we set up a discussion of how to classify and count structurally different offensive formations. The talk will be accessible to undergraduate mathematics students and football and non-football fans alike. (Received September 03, 2013)

1096-G5-775 **Daniel J. Lithio** and **Timothy J. Pennings*** (tpennings@davenport.edu), Davenport University, Department of Mathematics, 6191 Kraft Avenue, S.E., Grand Rapids, MI 49512, and **Eric M. Webb**. *Optimizing a Volleyball Serve.*

As explained by the Women's Volleyball coach, an optimal serve is one which is struck so as to clear the net and land within five feet of the net as quickly as possible. This talk explores how, at the request of the coach, two NSF-REU undergraduates and a professor developed a mathematical model involving gravity, air resistance and the spin of the ball in order to provide the coach with optimal serving strategies. In particular, we demonstrates all aspects of the mathematical modeling process including 1) making simplifying assumption in order to form a workable but realistic model, 2)developing (shoestring budget) methods to determine the various coefficients, 3) testing of the model, 4) using the model to predict optimal strategies, and 5)noting the end result as determined by victories on the court. (Received September 10, 2013)

1096-G5-1063 **Rick Cleary*** (rcleary@babson.edu) and **Fred Ledley**. *Moving On Up: Advancing Through the Ranks in Baseball and Medicine.*

Minor league baseball players attempt to move up through a number of levels, hoping to eventually make the major leagues. We examine the success rates at various steps of this process, and discuss similar processes in other sports and in business. In particular, we consider the case of medicines advancing through clinical trials to the 'major leagues' of being approved for use. We discuss the ways in which the sports and business processes could inform each other. (Received September 12, 2013)

1096-G5-1199 **Ben S Baumer***, Clark Science Center, 44 College Lane, Smith College, Northampton, MA 01063, and **Shane T Jensen** and **Gregory J Matthews**. *openWAR: An Open Source System for Overall Player Performance in Major League Baseball.*

Within baseball analytics, there is substantial interest in comprehensive statistics intended to capture overall player performance. One such measure is Wins Above Replacement (WAR), which aggregates the contributions of a player in each facet of the game: hitting, pitching, baserunning and fielding. However, current versions of WAR depend upon proprietary data, ad hoc methodology, and opaque calculations. We propose a competitive aggregate measure, openWAR, using public data, more rigorous methodology, and transparent calculations. We discuss a principled baseline compared to the nebulous concept of a "replacement" player. Finally, we use simulation-based techniques to provide variance estimates for our openWAR measure. (Received September 13, 2013)

1096-G5-1349 **Alexandra Iovine*** (aiovine.student@manhattan.edu), **Janie Schlauder** and **Helene R. Tyler**. *Pitch Perfect? Analyzing the Passing Networks of Manhattan College Women's Soccer.* Preliminary report.

We will report on the results of our fall 2013 research seminar in network theory. In a recent paper, Peña and Touchette [1] performed a network theory analysis of the 2010 World Cup soccer teams by viewing the players as nodes and the passes as arrows in a weighted directed graph. They used various centrality measures to quantify an individual player's importance and to describe how players are clustered within the network. Following their example, we worked to perform a similar analysis of the Manhattan College Women's Soccer team. This talk should be accessible to undergraduates with a solid background in linear algebra.

References: [1] J.L. Peña and H. Touchette. A network theory analysis of football strategies. http://arxiv.org/abs/1206.6904 (Received September 15, 2013)

1096-G5-1589 **William Schellhorn*** (william.schellhorn@simpson.edu). *The MLB All Star Challenge.*

Which Major League Baseball players should be selected for the All Star game? I posed this question to a group of research students that I advised and they used data mining techniques to produce a mathematical model that assigns accurate "All Star values" to batters. In this talk, I will first discuss the development of their model using the statistical software JMP and then present some related results. I will also offer suggestions about how to structure this type of undergraduate research project. (Received September 16, 2013)

1096-G5-1595 **Nicholas Taylor*** (nicholas.taylor@my.minotstateu.edu) and **Narayan Thapa** (narayan.thapa@minotstateu.edu). *Markov Chain Applications to Baseball Run Forecasting.*

A baseball general manager's goal is to field a competitive team of players while operating under defined financial restraints. In recent years, advanced baseball statistical research and analysis, spurred by Billy Beane's Moneyball A's, has driven many teams to install their own statistical divisions to demystify predictive uncertainty. In this presentation, we consider Markov Chains as a forecaster of a player's offensive potential to predict the team's run-scoring capacity. (Received September 16, 2013)

1096-G5-1756 **Reza D Noubary*** (rnoubary@bloomu.edu). *Survival Analysis of the Athletic Records.*

Sports provide an inexhaustible source of fascinating and challenging problems in many disciplines. Records set in different sports shed light on human strengths and limitations and provide data for scientific investigations, training, and treatment programs. This article presents a method for survival analysis of athletic records and demonstrates that using the data for the men's 100 meter dash. It uses threshold theory and the theory of records assuming attempts to break records occur either geometrically or according to a non-homogeneous Poisson process. (Received September 16, 2013)

1096-G5-2023 **Jonathan Sargent***, jonathan.sargent@student.rmit.edu.au, Melbourne, Australia. *A profitable adjustive rating system for NBA teams.*

This paper investigates an adjustive rating system for National Basketball Association (NBA) teams. Adjustive ratings in sport are derived from evaluations of the performance of a team or individual player—most often with prior performances in mind—where ratings increase, decrease or remain constant depending on above, below and met expectations respectively. With knowledge of NBA team and opponent pre-match ratings, and any home-court advantage, reasonable assumptions can be made regarding the outcome of a match between the two teams. This paper will demonstrate how fitting an Elo-influenced logistic curve to match data is profitable for betting on head-to-head markets in the NBA. Moreover, return on investment can be increased by optimising home-court advantage and margin of victory parameters with respect to the win likelihood in an impending match. Finally, a polynomial curve is fitted to the match prediction data to estimate a margin of victory, aiding in the determination of a team "covering the line". It is anticipated that this methodology will translate simply to other invasion sports such as soccer and hockey. (Received September 17, 2013)

1096-G5-2112 **Roland Minton*** (minton@roanoke.edu). *Effective Driving on the PGA Tour.* Preliminary report.

The wealth of professional golf data provided by the ShotLink system has resulted in numerous new statistics to measure golfing abilities. Driving statistics have traditionally bifurcated into distance and accuracy measures, with no widely accepted way of combining the two. Several driving statistics will be examined, including a new and very simple statistic for combining distance and accuracy. (Received September 17, 2013)

1096-G5-2172 **Dave I. Kennedy*** (dikenn@ship.edu), Shippensburg University, Department of Mathematics, Shippensburg, PA 17257, and **Ben Galluzzo** (bjgalluzzo@ship.edu), Shippensburg University, Department of Mathematics, Shippensburg, PA 17257. *How Math Can Lead You to Fantasy Football Glory.*

Fantasy Football provides a rich source of data for mathematical reasoning. We'll explore how to develop a mathematical model for drafting an expert-beating fantasy football team using concepts found in undergraduate math courses, particularly introductory statistics. Attention will also be given to the process of testing and improving the model. (Received September 17, 2013)

1096-G5-2271 **T. S. Michael*** (tsm@usna.edu). *How to Rate Bridge Players and Other Paired Competitors.*

In the current rating system, individual duplicate bridge players accumulate points based on their performance over the course of their careers. Thus the ratings measure frequency of play and longevity as much as playing strength.

We propose a new method that rates players based on the performance of their partnerships. Our method uses a least squares scheme to account for the strengths of a player's partners and opponents. The computations involve solving a linear system, whose matrix is of mathematical interest: an unsigned Laplacian matrix. The same method can be used to rate individuals in doubles tennis or other sports where individuals compete in pairs.

This is joint work with Tom Quint and Jeff Mortensen. (Received September 17, 2013)

1096-G5-2284 **E. Cabral Balriera** and **Charles D. Wessell*** (cwessell@gettysburg.edu), 300 North Washington Street, Campus Box 402, Gettysburg, PA 17325-1400. *The Minimum Number of Contests Needed for a Ranking Method to Approach Optimal Performance.*

If there is a "true" ranking of players or teams competing with one another, how many games need to be completed before a ranking method can determine that true ranking? Is that number impractical for a typical sports league? Answering these questions first requires examining how often, in a particular sport, a truly better team or player loses to an inferior one. With this information and using the schedule constraints of the major U.S. sports leagues, thousands of simulated seasons can be played with rankings computed after each day of play. These simulations can help us determine the number of games needed before playoff teams in the NBA and NHL be confidently predicted and help identify ranking methods that are particularly good at this kind of prediction. (Received September 17, 2013)

1096-G5-2436 **Milica Hadži-Tanović*** (milicaht@gmail.com), Mathematics Department, University of San Francisco, 2130 Fulton Street, San Francisco, CA 94117, and **Stephen Devlin** (stephenmdevlin@gmail.com), Mathematics Department, University of San Francisco, San Francisco, CA 94127. *A Network Based Method for Ranking NBA Players.*

We introduce a network structure on NBA players where individuals are connected when they play against each other during a period of time in an NBA game. Using readily available play-by-play data, we give weights to the network edges to allow for head-to-head comparisons between players based on in-game performance. Using this network structure, we formulate and solve a graph diffusion process to produce a ranking of players. We then compare and contrast the diffusion ranking with existing player rankings such as Player Efficiency Rating and Adjusted Plus-Minus, as well as with similar network based ranking systems used in other contexts including the methods of Keener and Colley, and Google PageRank. (Received September 17, 2013)

1096-G5-2482 **James T Snyder*** (jamestsnyder@att.net) and **John David**. *Machine Learning in NBA and NCAA Basketball.* Preliminary report.

In this paper we explore the ability of machine learning based mathematical models to make predictions of outcomes of National Basketball Association (NBA) and NCAA basketball games. We use statistics from the 2004-2005 season up to and including the 2008-2009 season to evaluate the predictive capabilities of our models. We implement machine learning techniques to build models in order to make predictions on the score differential between two teams in a given game. Ensembles of Artificial Neural Networks (ANNs) and Decision Trees (DTs) are built based on data from two previous seasons and then used to predict the next season. The average accuracy over all predictions from 2006-2009 was 70.9% for the NBA and 76.5% for the NCAA with mean errors of 8.9 points per game and 8.1 points per game, respectively. We suggest various hypotheses for why the model is able to predict NCAA games with higher accuracy and less error. Further, we perform a model analysis where we examine the importance that each model places on the input statistics and compare the results. (Received September 17, 2013)

1096-G5-2503 **Danielle Shepherd*** (dshepherd14@wooster.edu), 1189 Beall Ave., Wooster, OH 44691, and **Timothy Chartier** and **Kenneth Massey**. *When Do We Know? Using Mathematics in NASCAR ranking.*

In the NASCAR Sprint Cup Series, the Chase is a major event, bringing with it increased drama and pressure for all teams and members. The question is always which drivers will be in and which drivers will be out. The ranking of the drivers is based on a cumulative point system where drivers acquire points based mainly on their finishing position although leading laps and winning a race increases the number of points received. The goal of our work is to analyze the correlation between the NASCAR points ranking system and the rankings systems we develop mathematically. By solving large systems of linear equations, rankings for drivers can be computed. Comparing these to the NASCAR driver rankings, the correlation between the two different ranking methods can be determined. The ultimate goal would be to create a ranking system and know at what point in the season that ranking system could accurately determine the drivers who would make the Chase. This would allow teams to know who their greatest competitors were for those coveted ten spots. (Received September 17, 2013)

1096-G5-2521 **Charles Bergeron*** (chbergeron@gmail.com), Albany College of Pharmacy, and Health Sciences, 106 New Scotland Avenue, Albany, NY 12208. *Discovering athlete treatment modalities at the Pan-American Games.* Preliminary report.

We are studying a dataset consisting of 1957 encounters between an American athlete and a medical provider during the 2011 Pan-American Games. This is a fast-paced environment where time and resources are limited. Each encounter documents the athlete (sport, gender), provider (physiotherapist, medical doctor, etc.), the nature of the athlete's complaint and which of 20 treatments were applied (the treatment space). Applying principal components analysis (PCA) to the treatment space, we find 3 leading components explaining 72% of the variability. Their PCA scores reveal 4 clusters (or modalities) that are interpretable: Recovery-Performance Enhancement, Soft Tissue Mobilization with Spinal Manipulation, Soft Tissue Mobilization without Spinal Manipulation and General Medical. Each cluster is dominated by specific sports, complaints and provider types, providing valuable insights into what medical issues athletes face and how providers approach these issues.

These modalities can be further refined to obtain 20 submodalities that are even more specific. This research foreshadows sport- and provider- specific models that can be used to better train providers prior to multisport events such as the Olympics. (Received September 17, 2013)

1096-G5-2526 **Andrew B. Perry*** (aperry@springfieldcollege.edu). *Sports Analytics with Elementary Math.*

In the Fall 2012 semester, the author was charged with developing a Sports Analytics class at Springfield College. This class was to demonstrate the power of mathematics to students with modest math backgrounds, and to do so in a manner that would captivate the many sports fans in the college's student body. This talk will discuss some of the most intriguing units developed for this course- some of which may be able to be incorporated into traditional courses like algebra and statistics. For example, this course analyzes the mathematics behind decision making in football: when to punt, when to attempt a two point conversion, and when it may even sense to take a knee at the opponent's goal line when it might be possible to score a touchdown. In baseball, we consider efforts to quantitatively measure the offensive production of batters with a single number. (Received September 17, 2013)

1096-G5-2628 **Jeffrey W Heath*** (jeffrey.heath@centre.edu), 600 W. Walnut St., Danville, KY 40422, and **Alexander L Cope**. *A New Basketball Defensive Efficiency Metric.*

In the NBA, 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 data from 2007 to 2012, we developed a regression model for measuring 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 17, 2013)

1096-G5-2703 **Calla Glavin*** (calla.glavin@usma.edu), Department of Mathematical Sciences, West Point, NY 10996, and **Brian Macdonald** (brian.macdonald@usma.edu), Department of Mathematical Sciences, West Point, NY 10996. *Estimating Goal Probabilities in the NHL.*

We estimate the probability that an NHL shot will be a goal based on several details of the shot. Predictors include information like shot location, and whether or not the shot was a rebound shot. We also use the goalies and the shooters involved in each shot as predictors. The results of the model are used to analyze goalies, shooters, team offenses, and team defenses. For example, the coefficient for a goalie can be used to form an adjusted save percentage statistic for that goalie which accounts for the quality of shots that he faces. (Received September 18, 2013)

1096-G5-2707 **Brian Macdonald***, Department of Mathematical Sciences, West Point, NY 10996. *Predicting team and player performance in hockey.*

We'll give an introduction to predicting team and player performance in hockey. We'll discuss problems with some traditional statistics, many of which are based only on goals, or do not take into account things like strength of opponents. We then discuss some advanced statistics that deal with these issues. (Received September 18, 2013)

1096-G5-2719 **Jeff Hamrick*** (jhamrick@usfca.edu), University of San Francisco, School of Management, 2130 Fulton Street, San Francisco, CA 94117. *Are Umpires Racist?*

We investigate the racial preferences of Major League Baseball umpires as they evaluate both pitchers and hitters from 1989-2010, including the 2002-2006 period in which "QuesTec" electronic monitoring systems were installed in some ball parks. We find limited, and sometimes contradictory, evidence that umpires unduly favor or unjustly discriminate against players based on their race. Variables including attendance, terminal pitch, the absolute score differential, and the presence of monitoring systems do not consistently interact with umpire/pitcher and umpire/hitter racial combinations. Most evidence that would first appear to support racially-connected behaviors by umpires vanishes in three-way interaction models. Overall, in contrast with some other literature on this subject, our findings fall well short of convincing evidence for racial bias. (Received September 18, 2013)

Mathematics Experiences in Business, Industry, and Government

1096-H1-216 **Andy Niedermaier***, 1 New York Plaza, 33rd Floor, New York, NY 10004. *Orderly Chaos (in the Stock Market).*

"Those darned high-frequency traders! They caused the Flash Crash! They must be stopped!" This has been a pretty common sentiment since the events of May 6, 2010. And for good reason! *You* weren't furiously buying and selling stocks during the crash, were you? No, *computers* were!

Well, actually, it's a *little* more complicated than that. What I'd like to do is take some time to talk about the Flash Crash, the market regulations that have evolved in its wake, and some of the math one can use to measure the impact of such regulation. Ultimately my goal is to illustrate the complexity of the core set of logistical problems that securities exchanges face today, and how quantitative traders (like myself!) think about market structure. (Received August 20, 2013)

1096-H1-316 **John Sadowsky*** (john.sadowsky@jhu.edu), Zeta Associates Incorporated, 10302 Eaton Place, Fairfax, VA 22030. *An Application of Computational Algebraic Geometry to Real-World Signal Processing Problems in an Industrial Organization.* Preliminary report.

Computational Algebraic Geometry is an exciting field of mathematics that has experienced significant research and development activity over the past 25 years. New algorithms for Groebner bases, reducing Sylvester matrices, and so forth have resulted symbolic algebraic approaches to algebraic varieties, the zeros of systems of multivariable polynomials. These results could as well apply to real-world problems in industry, in which systems producing detected signals are modeled as intersections of systems of multivariable polynomials. Usually, such problems are handled by methods of iteratively approximating the intersections, because the computational algebraic geometry requires exact values of coefficients and exact arithmetic, but in the real world, measurements are approximate and computer arithmetic approximates the real field as floating point, both in representation and computation. There are times, however, when it is important to understand the geometry of the algebraic variety and not simply numeric values for some of the zeros in that variety. This talk will present experience in industry with developing algorithms to solve such problems, combining the algebraic geometric algorithms with numerical techniques and a multi-precision library of C++ arithmetic functions. (Received August 27, 2013)

1096-H1-468 **Tim Andersen*** (tim@va.wagner.com), 2 Eaton St., Suite 500, Hampton, VA 23669, and **C Allen Butler** and **Michael Mascagni**. *Memory Efficient Lagged Fibonacci Random Number Generators for GPU Supercomputing.*

Graphics Processing Units (GPUs) bring the promise of supercomputing power for a fraction of the cost of traditional supercomputing, with speed-ups over comparable CPU hardware of one or two orders of magnitude. Rapid development of both proprietary libraries such as NVIDIA's CUDA and an open standard, OpenCL, have opened the doors to their cheap computing power. Unfortunately, random number generators (RNGs) have been slow to catch up with the rapid expansion of GPU computing. The number of types of RNGs available for GPUs is small, and the statistical quality of those provided with standard libraries frequently unknown. Because specific RNGs only have statistical quality for certain applications, new kinds of RNGs must be made available for GPU computing to bring the full power of GPUs to different kinds of research. Lagged Fibonacci Generators, in particular, have been difficult to develop for memory-lacking GPUs because of their large state space, which is unfortunate because they have excellent statistical properties for many applications. In this talk, we discuss our implementation of a memory efficient additive LFG for both CUDA and OpenCL. We also discuss reproducibility and portability. (Received September 04, 2013)

1096-H1-620 **Brandon R Theiss*** (brandon.theiss@rutgers.edu), 20 Livingston Ave Unit 602, New Brunswick, NJ 08901. *A Starbucks Coffee in less than 5 minutes?* Preliminary report.

In the retail service industry, speed of delivery of a particular service is a critical metric tied directly to customer satisfaction. While waiting for services, customers will exit queues should they believe the time spent in the queue is or will be too long. Customers who pay prior to receiving a service and are then subjected to unacceptably long throughput times are unlikely to return. The combined customer wait time is tied to their perception of the quality of the service.

This research first attempts to define and parameterize the wait times that a customer experiences. It then explores the performance of the retailer to meet customer expected wait times. Finally, this research the case of a customer who has flexibility and discretion in selecting a time to arrive at the store and will adopt a strategy to minimize expected wait yet is constrained to arrive between 8 and 9AM.

In order to accomplish these research objectives an observational study was performed over a 6 week time period which resulted in over 3,000 observations. This data was than analyzed, modeled and simulated to answer the initial research questions in addition to propose process changes to the retailer to improve their customers satisfaction through decreased wait times. (Received September 08, 2013)

1096-H1-731 **Kathryn A Haymaker*** (s-khaymak1@math.unl.edu), 203 Avery Hall, Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588, and **Alexandra Seceleanu**. *Math in the City: Modeling ground water cycles based on local data.* Preliminary report.

Math in the City is a project-based course for undergraduate students designed to investigate real-world applications in the local community. The current project is centered around modeling the effect of ground water usage on the natural water cycle, using data on well levels in eastern Nebraska. The topic is timely, given the recent drought and concerns about water usage in the midwest. In order to put the data in context and interpret the results, participants in the class are collaborating with an employee at the local Natural Resources District, a Nebraska government agency that handles natural resources management. This talk will cover the design and implementation of such a course as well as results from the recent project. (Received September 09, 2013)

1096-H1-828 **William P. Fox*** (wpfox@nps.edu), Department of Defense Analysis, NPS, Monterey, CA 93943. *Modeling to Help Government & Military Decision Making.* Preliminary report.

We teach multi-attribute decision making in our three course sequence but limit our discussion to data envelopment analysis, Analytical Hierarchy Process, and TOPSIS. We also teach many regression techniques including nonlinear, logistics, and Poisson. We have built mathematical models to analyze terrorist risk, selection of General Officers, terrorist network assessment, as well as other related terrorist or insurgent activities using these techniques. We present modeling evidence as to how insurgencies or terrorist networks grow with an example from the Philippines. We also present evidence of interdiction of terrorist activities based upon real unclassified data. (Received September 10, 2013)

1096-H1-857 **Ellina V Grigorieva*** (egrigorieva@twu.edu), PO BOX 425262, Denton, TX 76204, and **Evgenii N Khailov**. *Optimal production- sales strategies for a company at changing market price.*

A production-sales activity of a company is modeled by a nonlinear control differential equation of the dynamics of the production funds. The company produces a single consumer good, the demand on which always exists. The market price depends on the volume of the produced goods described by the Cobb- Douglas production function. The model has two bounded controls: 1. the share of the profit, $u(t)$, obtained from sales that the company reinvests into expanding own production, and 2. the amount of short-term loans, $K(t)$, taken from a bank for the same purpose. The problem of maximizing discounted total profit on a given time interval is stated. In order to find the optimal product-sales strategies for the company, the Pontryagin Maximum Principle (PMP)is used. It is proven that PMP is the necessary and sufficient condition for the optimality. In order to investigate the arising two-point boundary value problem for the maximum principle, an analysis of the corresponding Hamiltonian system is applied. Based on a qualitative analysis of the Hamiltonian system, our conclusions about the optimal solutions to the stated profit maximization problem are made. The results of numerical calculations for different model's parameters and their economic analysis are presented. (Received September 10, 2013)

1096-H1-1154 **James H. Fife*** (jfife@ets.org), Educational Testing Service, Mail Stop 18-E, 660 Rosedale Road, Princeton, NJ 08541. *Modeling the Key and Keying the Model: Combining Automatic Item Generation with Automated Scoring.*

Automatic item generation has been shown to be a cost-effective means of generating multiple-choice mathematics items (Bejer et al., 2003; Drasgow et al., 2006; Gierl et al., 2008; Alves et al., 2010). For constructed-response items, however, the cost-effectiveness disappears unless the items can be automatically scored and the automated-scoring models of the instances generated automatically. In this talk, two approaches to the automatic generation of automated-scoring models will be discussed; these approaches have been called "modeling the key" and "keying the model" (Graf & Fife in Gierl & Haladyna, 2012). (Received September 13, 2013)

1096-H1-1177 **John A. David*** (davidja@vmi.edu), Virginia Military Institute, 430 Mallory Hall, Lexington, VA 24450. *Applied and Industrial Mathematics Program at the Virginia Military Institute.* Preliminary report.

The Applied and Industrial Mathematics (AIM) program at the Virginia Military Institute is an undergraduate research and consulting program administered by the Applied Mathematics Department. AIM employs cadets during the summer to work on problems for laboratories, businesses, government and not for profits. It has performed work for both local and national organizations. The program is modeled after a similar program at the College of Wooster. It was founded in the summer of 2011 and has since completed 10 projects. It is primarily funded by clients, but supplemental funds have been provided by the institute. This talk will outline the program and discuss specific results from several projects.

- Building software to find optimal delivery routes for hot lunches for elderly clients.
- Creating a computational model to identify manpower and equipment needs to detect pirates.
- Developing databases for energy use and community needs statistics.

(Received September 13, 2013)

1096-H1-1247 **Gregory E Coxson*** (coxson@radar.nrl.navy.mil), Code 5344, Building 60, NRL, 4555 Overlook Avenue, SW, Washington, DC 20375, and **Grant Izmirlian**. *Application of Cluster Analysis to the MAA Member Database.* Preliminary report.

MAA section meetings are relatively inexpensive, informative, often convenient, and a great way to get to know institutions of higher education in your area. However, section geography can pose challenges. We considered the question of whether a new set of section boundaries might yield a smaller average member distance to section meeting venues, offering the possibility of greater participation at section meetings. Among the approaches considered, K-Means Cluster Analysis proved a fruitful approach yielding enlightening results. This talk will describe the approach, the results achieved, and suggestions for adjustments to the current set of 29 sections. (Received September 13, 2013)

1096-H1-1543 **James R. Bozeman*** (james.bozeman@lyndonstate.edu), Mathematics and Computer Science, Lyndon State College, 1001 College Road, Lyndonville, VT 05851, and **Timothy Nicholson**, **Matthew Pilling** and **Melissa A. Rosato**. *Use Convexity, Not 'Compactness', When Measuring the Shape of Legislative Districts.*

Many states use 'compactness' measures when constructing political districts. Numerous studies have pointed out the many flaws associated with these methods. More recently measures which use the mathematical idea of convexity have been examined. In this paper we exhibit a convexity measure which is better than, or at least as good as, other methods in the literature. This technique can then be used to decide if proposed districts are *nicely shaped* or not. A *poorly shaped* district may indicate partisan gerrymandering, which many states are trying to avoid. (Received September 17, 2013)

1096-H1-1601 **Carol Brown** and **Rachel R Roe-Dale*** (rroedale@skidmore.edu), Skidmore College, Math and Computer Science Dept., 815 North Broadway, Saratoga Springs, NY 12866, and **Mark Staton**. *Modeling the Diffusion of Manual Irrigation Pumps.* Preliminary report.

Modeling the diffusion of products and innovations is a rich field of research that is of interest to marketers, forecasters, economists, and business managers. The Bass model, an ordinary differential equation which describes product adoption over time, has been extensively studied and used to model sales data for the diffusion of many products. In this study we use the Bass model to analyze the diffusion of manual irrigation pumps in populations below the poverty line in Bangladesh, Tanzania, and Kenya. We also make conclusions regarding the values of the parameters estimated for the Bass model and the process of product adoption in economies at the base of the economic pyramid. (Received September 16, 2013)

1096-H1-2081 **Michael Dorff*** (mdorff@math.byu.edu), 310 TMCB, Department of Mathematics, Brigham Young University, Provo, UT 84603, and **Linda Braddy**, **Reza Malek-Madani** and **Suzanne Weekes**. *A New National Program: Preparing Students for Business, Industry, and Government.*

We are beginning a new program to prepare students in the mathematical sciences to succeed in careers in business, industry, and government (BIG). Funded by a $2 million NSF grant, this program will (a) help undergraduate mathematical sciences majors be aware of their choices for non-academic careers and opportunities for internships, (b) help mathematics faculty be more fully aware of non-academic career options for their students, make connections with people working for local BIG organizations, and develop internship opportunities for their students, (c) offer undergraduate students the opportunity to have a research experience related to real-world problems from BIG, and (d) provide training to undergraduate students and faculty in how to successfully work on problems from BIG and develop the needed communications skills. To accomplish these objectives, we will develop a set of educational and informative videos, conduct summer training workshops for faculty, organize a semester-long course and competition for undergraduate students containing a strong undergraduate research component, and organize a summer recognition conference for participating undergraduate students. (Received September 17, 2013)

1096-H1-2116 **Thomas Höft*** (hoft@stthomas.edu), University of St. Thomas, 2115 Summit Ave., Mail OSS 201, Saint Paul, MN 55105. *A 3-D face imaging method with applications to biometric identification.*

We review a three-dimensional imaging method, Fourier transform profilometry (FTP), and present an example of its use in industry for biometric identification of humans. In FTP one projects single-frequency sinusoidal fringes of laser light onto an object and records a digital image; the depth profile of the object distorts the fringes, encoding 3-D information as a modulation of the fringe frequency. The Fourier transform allows for computationally efficient recovery of a depth image. Data is acquired from the face of a minimally co-operative human subject and processed to produce a 3-D surface of the face. Paired with a co-registered photograph, the surface may be rotated to a standard mug-shot pose for biometric identification. We illustrate the method with data from real live humans. (Received September 17, 2013)

1096-H1-2363 **Genevieve Brown*** (genevievebrown2008@u.northwestern.edu) and **Sean Lynch**. *A New Basis for Graph Partitioning: Standardizing the Interactions Matrix.*

Several popular graph partitioning algorithms (CNM, Louvain) attempt to optimize a quantity called modularity, however, modularity based algorithms suffer from a "resolution limit" and thus fail to identify small communities within a graph. McCloskey et al. (2010) proposed a correction to this by introducing a standardizing factor into modularity. In addition, they present a graph matrix derived from a linear statistical model called the Interactions matrix as a candidate for spectral partitioning and investigate its theoretical connections to other graph matrices.

Noting the success of standardizing modularity, here we develop a new matrix for spectral graph partitioning by standardizing the Interactions matrix. Following an analogous path to that taken by McCloskey et al. we model the adjacency matrix with a multinomial random variable and make an independence assumption. We use the model to calculate distribution quantities for the Interactions terms and thus obtain the Standardized Interactions matrix. Finally, we manipulate the matrix and obtain an approximate form suitable for large scale implementation. Partitioning results are investigated and presented via examples and comparisons against existing algorithms. (Received September 17, 2013)

1096-H1-2463 **Eduardo Cotilla-Sanchez**, **Mahantesh Halappanavar** and **Emilie Hogan*** (emilie.hogan@pnnl.gov), P.O. Box 999, MSIN K7-90, Richland, WA 99352. *Clustering on the Power Grid.*

As the electrical grid increases in size there is focus on reducing the size of the simulation space. One way that this can be done is to group generators together that have similar behavior. In this talk we will describe three techniques to cluster generators based on spectral clustering and modularity clustering, both forms of graph clustering, and k-means with a genetic algorithm. We will compare our methods on two data sets. This work is done as a collaboration between Pacific Northwest National Laboratory and Oregon State University for the Department of Energy's Advanced Scientific Computing and Research program. (Received September 17, 2013)

1096-H1-2687 **Charles Tannouri*** (ct.correspondence@gmail.com). *Data Stranglehold or: How the Government Can Learn to Stop Worrying and Love Math.*

Among the greatest challenges facing leaders in the public sector is a lack of reliable data to guide decision making. Whether due to aging data infrastructure or prohibitions on data sharing, strategies and operations executed in the absence of strong data-driven recommendations can open an organization to scrutiny, liability, and even disaster.

A hypothetical case study is proposed to illustrate obstacles facing public sector decision makers as well examine possible solutions. Supplementing a multi-criteria decision analysis technique with an open-source neural network implementation, public information is used to develop proposed solutions to sensitive policy issues and operational problems. (Received September 17, 2013)

Open Source Mathematics Textbooks

1096-H5-81 **Ken Levasseur*** (kenneth_levasseur@uml.edu), Department of Mathematical Sciences, 1 University Ave., Lowell, MA 01854. *What a Difference 30 Years Makes! - Adventures in Mathematics Textbook Publishing.*

This talk describes a journey that begins with a Wang word processor and ends with free pdf downloads, Mathematica Notebooks and Sage cells. After writing and publishing a discrete mathematics textbook through a commerical publisher in 1984 and having it revised for 1989, the authors of Applied Discrete Structures (for Computer Science) secured their copyright in 2010. After a a major revision, the book is now an open content text under a Creative Commons license (BY-NC-SA). The speaker will outline the history of the project and the process by which the text has reached its current state. (Received July 15, 2013)

1096-H5-140 **Richard Hammack*** (rhammack@vcu.edu). *A do-it-yourself guide to print on demand publishing.*

Print on demand technology is a convenient and very inexpensive medium for producing and distributing textbooks. This talk is a do-it-yourself guide for authors wishing to publish their open-source textbooks through print on demand. I share knowledge gained from publishing my own textbook, including tips on production, setup, distribution and promotion. (Received August 08, 2013)

1096-H5-345 **Thomas W Judson*** (judsontw@sfasu.edu), Department of Mathematics and Statistics, Stephen F. Austin State University, P.O. Box 13040-3040 SFA Station, Nacogdoches, TX 75962, and **Robert Beezer** (beezer@ups.edu), Mathematics & Computer Science, University of Puget Sound, 1500 N. Warner, Tacoma, WA 98416. *Experiences from Publishing Open Source Textbooks.*

Writing, promoting, and maintaining an open source textbook can be quite different than following the established route of publishing a textbook with a commercial publisher. We will present our experiences publishing open source textbooks in abstract algebra and linear algebra, discussing the advantages and disadvantages of publishing open-source materials. We will also discuss how to promote and maintain an open source textbook as well as future directions, including authoring in XML to facilitate publishing in different formats. (Received August 29, 2013)

1096-H5-350 **David Lippman*** (dlippman@pierce.ctc.edu), 9401 Farwest Dr SW, Lakewood, WA 98498. *Open online homework and courses to support open textbooks.*

Many colleges have come to rely on online homework in courses like developmental math, college algebra, precalculus, trig, and calculus. This can pose a barrier towards adopting open source textbooks. To address this, numerous schools have collaboratively developed full online course frameworks on the IMathAS/MyOpenMath open source online homework platform. These frameworks combine open source text material, video resources, and text-aligned online homework for these courses. The capabilities of the platform will be shown, and a few of the course frameworks will be demonstrated. (Received August 29, 2013)

1096-H5-392 **John Wesley Cain*** (jcain2@richmond.edu,jcain2@math.harvard.edu), University of Richmond (Mathematics and CS), Harvard University (Mathematics). *To Make Free Or Not to Make Free—That is the Question.*

In this presentation I will relate some of my experiences in co-authoring two texts on differential equations, one published commercially and the other available open-access. There are advantages and disadvantages to each approach, many of which I had not anticipated. Audience participation is strongly encouraged. (Received September 01, 2013)

1096-H5-572 **Matt Boelkins*** (boelkinm@gvsu.edu), Department of Mathematics, Grand Valley State University, Allendale, MI 49401. *If you love something, (how to) set it free.*

I have always loved teaching calculus. I always hated having my students pay $150 for a textbook for the course, especially for a text I didn't really like. So, I wrote a free, open-source calculus text.

In this talk I plan to tell the story of how, with the assistance of some of my colleagues, I wrote a two-semester text in a year's time and made it publicly available, as well as some of the things I've learned in the year since. In particular, this talk will address such questions as: how much time will the project take? what sorts of technology are important to use? what are some possible ways to publicize the finished product? how can you gain peer validation of your work? why is publishing or using a free text superior to using a for-profit version? what will I do differently for the next free, open text I write? (Received September 06, 2013)

1096-H5-624 **David W. Farmer*** (farmer@aimath.org). *How to write LaTeX that can be converted to various formats.* Preliminary report.

Open textbooks need to be viewable in multiple formats, such as PDF for printing or HTML for viewing in a browser or mobile device. The LaTex source, as well as the source files for any images, also have to be available or else the book is not truly "open."

Since LaTeX is a full programming language, it is possible to write LaTeX which is extremely difficult to convert to HTML. I will describe some simple principles for structuring LaTeX in a way that allows the conversion to be done more easily. Some key points are to use macros which add to the semantic structure of the document, to have all environments include a labeled beginning and ending, and to avoid nested structures. Following these principles makes it possible to do the conversion using regular expressions, avoiding the need to completely parse the document. (Received September 08, 2013)

1096-H5-684 **Jim Hefferon*** (jhefferon@smcvt.edu), Box 187, Saint Michael's College, Colchester, VT 05439. *Groups and Fields in Open Text Authoring.*

Most open source mathematics books now available are due entirely to a single person. But in the wider world, many books are improved by the work of groups of specialists from various fields: by graphic information artists, by people who develop exercises and ancillary material including answers to exercises, by translators, and by editors, typographic designers, and marketers. In addition, more and more mathematics books will include sophisticated multimedia, dynamic elements that must be programmed, and may involve versions for various display engines or platforms. Few authors are expert at, or have the resources for, all of the work needed to make a maximally useful document. We must come to see at least some of these projects as more like software: community-centered joint work by a number of experts, and under continuous deployment. Part of this change of thinking must be the development of funding sources. (Received September 09, 2013)

1096-H5-780 **Ted Sundstrom*** (sundstrt@gvsu.edu), Department of Mathematics, Grand Valley State University, Allendale, MI 49401. *Be a Socialist and a Bit of a Capitalist.*

We no longer need to rely on commercial publishers to produce professional quality textbooks. We now have the tools to do this on our own. We can produce a book that is freely available to download as a pdf file and publish it as a low-cost (< $20) print-on-demand version.

In 2002, the first edition of an introduction to proofs textbook that I wrote was published by a commercial publisher and it has been on the market since then. This talk will be about my journey during 2013 of taking this book from the commercial publishing world to the world of publicly available, free books, what I have learned about textbook writing and publishing, how this can be applied to publishing books that are freely available, and how to create a low-cost print version of a book. (Received September 10, 2013)

1096-H5-930 **Gregory Hartman*** (hartmangn@vmi.edu), 427 Mallory Hall, Virginia Military Institute, Lexington, VA 24450, and **Troy Siemers**. *$\mathrm{A^P_E X}$: A Collaborative Model for Open-Source Textbook Writing.*

In this talk we introduce a collaborative model of textbook writing called $\mathrm{A^P_E X}$ (Affordable Print and Electronic teXtbooks). In order to produce a high-quality text, a great deal of time must be invested and expertise is needed in areas both inside and outside of mathematics. The $\mathrm{A^P_E X}$ model mitigates the costs to individuals. Advantages and difficulties presented by this model (some of which were learned through our personal experiences) will be discussed. We also outline motivations for participating in open-source textbook writing, including both personal and professional interests. (Received September 12, 2013)

1096-H5-1155 **Nathan Friess*** (nathan@lyryx.com), Lyryx Learning Inc., #205, 301 - 14th Street N.W., Calgary, Alberta T2N 2A1, Canada, **Claude Laflamme** (laflamme@ucalgary.ca), University of Calgary, Dept of Mathematics & Statistics, 2500 University Dr, Calgary, Alberta T2N 1N4, Canada, and **Robert Woodrow** (woodrow@ucalgary.ca), University of Calgary, Dept of Mathematics & Statistics, 2500 University Dr., Calgary, Alberta T2N 1N4, Canada. *OER blended model.*

Open Education Resources (OER) have the potential to make radical changes in the (higher) education system. The price is certainly right, but they are time consuming to edit and adapt, and typically provide only some of the resources necessary to teach large enrollment courses.

We will present preliminary results on a pilot being currently conducted by Lyryx Learning at the University of Calgary offering: * An open text adapted to the target course and professionally edited by the Lyryx editorial team. * Corresponding formative online assessment used for day to day homework practice. * Daily email support to all students and instructors. * Supplementary material, including beamer presentation slides.

All this with FREE access in University computer labs, and available at the regular $39.95 license price for access elsewhere.

Available data will include student perception of open text quality, student perception of quality and effectiveness of online homework for learning purposes, proportion of students opting for free/paid access, and correlation of online assessment with final course grades (including for those students only accessing the material for free). (Received September 13, 2013)

1096-H5-1400 **Jeff Zeager*** (jzeager@lorainccc.edu), Division of Science and Mathematics, Lorain County Community College, 1005 Abbe Road North, Elyria, OH 44035. *Avoid "Imperial Entanglements" and Other Advice from two Open-source Authors.*

Carl Stitz and Jeff Zeager have spent a fair amount of the last five years writing and editing an open-source Precalculus book. In this talk the authors give a brief history of their project and then share the lessons they've learned the hard way. Specific topics include the benefits of our partnership with WebAssign, the importance of understanding state-level course transfer policies and, as the titles suggests, why prospective authors and adopters of open-source materials need to avoid "Imperial entanglements". Anecdotes about fighting with LaTeX, arguing about the definition of local maximum and choosing a font for the upcoming 4th edition should keep this talk from becoming as tedious as editing the index of a 1100-page Precalculus book. (There's a story about that, too.) (Received September 15, 2013)

1096-H5-1557 **Nicole Allen*** (textbooksnicole@gmail.com), 21 Dupont Circle NW, Suite 800, Washington, DC 20036. *Open Textbooks and Solving the Textbook Cost Crisis.*

The average U.S. college student spends more than $1,000 per year on textbooks and supplies, a significant expense on top of already burdensome college costs. Textbook prices continue to skyrocket faster than inflation, and textbooks in introductory subjects frequently cost over $200 a piece. The U.S. market is estimated at $8.8 billion, with just five publishers in control of the vast majority of sales.

Open textbooks offer a compelling and common-sense solution to these challenges. With today's rapidly changing student preferences, open textbooks could revolutionize the way textbooks are bought and sold - the full text is offered free online, affordable hard copies can be sold in the bookstore, and a wide range of print and digital formats are available online. This virtually eliminates affordability concerns while enabling all students to have unfettered access to the text starting the first day of the course.

This session will provide an overview of the issue of textbook affordability and the need for open textbooks as a solution: what the latest research shows, who the biggest players are, where the market is likely to go, and how it could improve mathematics education. (Received September 16, 2013)

1096-H5-2229 **D Scott Dillery*** (dillerys@lindsey.edu), 210 Lindsey Wilson St, Columbia, KY 42718. *Accessibility and Open Source.*

Many in the open source community are driven to make materials more accessible with respect to cost and distribution. In addition, the community should publish with other accessibility issues in mind. This talk gives examples of how textbooks and WeBWorK problems can be designed for more inclusion and references to various accessibility initiatives. (Received September 17, 2013)

1096-H5-2640 **Joe Fields*** (fieldsj1@southernct.edu). *You say tomato and I say tomato. . . .*

Stylistic issues (even slight ones) may influence the decision to adopt a textbook. One of the most important benefits of open-source texts is the freedom that adopters are granted to modify them as they see fit. But, is this freedom illusory? Will a professor who is considering an open-source text invest the effort necessary to tweak it to suit their desires? Or, are they more likely to say something on the order of "That book does x, and I want a book that does y, so I'm not using it!"? Commercial publishers routinely offer multiple versions of their top-selling books. Should the authors of open-source books do likewise? I will discuss the issues – technical, pragmatic and philosophical, about offering an open-source book (and related adjunct materials) in multiple versions. (Received September 17, 2013)

Programs and Approaches for Mentoring Women and Minorities in Mathematics

1096-J1-581 **Elizabeth A. Burroughs*** (burroughs@math.montana.edu), Department of Mathematical Sciences, Montana State University, Bozeman, MT 59717. *Grant-Writing Resources: Supporting Women Faculty in STEM through Mentoring.*

Montana State University is a large land grant institution in the Rocky Mountain West with both very high research activity and very high undergraduate engagement. Women faculty members who advise and teach undergraduates have the potential to provide our students with role models who are active researchers in science, technology, engineering, and mathematics (STEM) fields. But with women comprising just over 20% of faculty members in the mathematical sciences and in STEM fields overall, MSU has room to grow the numbers of women faculty. Supported by an NSF ADVANCE program grant, we have begun a university-wide process of institutional transformation through initiatives designed to support women faculty members.

One of the initiatives is intended to provide research support to women faculty in STEM. The support includes a grant submission training coordinator and a grant facilitator network, both of which provide mentoring and other resources for women faculty in STEM. I will highlight the mentoring component of the grant-writing support provided for faculty members, and will share the theoretical foundations for the initiatives and showcase our resources. I invite discussion from participants about how these initiatives and supports could be adopted at other institutions. (Received September 06, 2013)

1096-J1-1075 **Kate G. McGivney*** (kgmcgi@ship.edu), Mathematics Department, 1871 Old Main Dr., Shippensburg, PA 17257, and **Sarah N Bryant**. *Retaining and Advancing Female STEM Faculty at Teaching-Focused Institutions.* Preliminary report.

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 with funding provided by the NSF. STEM-UP PA's goal is to support the recruitment, retention, and advancement of academic faculty women in STEM fields.

We will discuss programs and related findings from two of STEM-UP PA's initiatives. These initiatives are based on programs developed at Research 1 universities and have been successfully adapted to support faculty women at teaching-focused institutions. The Mentoring Network initiative is aimed at increasing retention of STEM academic women and reducing isolationism via one-to-one mentoring. Our Mentoring Network is a year-long program that pairs junior female faculty with a mentor based on similar goals. We will discuss the on-going assessment of this program. OASIS is a year-long leadership development program in affiliation with Rutgers University that supports academic STEM women through a combination of skills workshops, peer-mentoring, one-to-one coaching, and networking opportunities.

Assessment results, brochures, and our website will be shared with participants. (Received September 12, 2013)

1096-J1-1792 **Yu-Ju Kuo*** (yjkuo@iup.edu) and **Rick Adkins** (fadkins@iup.edu). *Establishing an interdisciplinary cohort to increase females and minorities in mathematics.*

The Scholarship-Creating Opportunities for Applying Mathematics (S-COAM) program at Indiana University of Pennsylvania (IUP) has been funded by the NSF S-STEM program since 2010 (Award No. DUE 0966206 & DUE 1259860). The S-COAM program provides financial support, mentoring, and professional development opportunities to STEM undergraduates majoring or minoring in mathematics and graduate students in the M.S. in Applied Mathematics program at IUP with emphasis of increasing the number of females and minorities completing their degrees. Since 2010, the program has funded 64 different students including 28 females and five minorities. Among 21 currently funded undergraduates, there are 12 female students and two are minorities. Among ten female undergraduate students who graduated prior to Fall 2013, five continued into their master's or Ph.D. programs. In this presentation, we will share our recruiting efforts, cohort activities, and female students' feedback for the program, as well as identify effective strategies based on the literature research and the program assessments. (Received September 16, 2013)

1096-J1-2164 **Semra Kilic-Bahi*** (skilic-bahi@colby-sawyer.edu), 541 Main St., New London, NH 03257. *Secret Communication Summer Camp.*

This talk will focus on a summer camp designed for middle and high school students on cryptology. The development and implementation of this camp is largely funded by the MAA Dolciani Mathematics Enrichment Grant. The resources, range of activities used, and assessment results will be emphasized throughout the talk. (Received September 17, 2013)

1096-J1-2251 **Gulden Karakok*** (gulden.karakok@unco.edu), 501 20th Street, Campus Box 122, Greeley, CO 80639, and **Brian Christopher**. *National Research Experience for Undergraduates Programs: A Mathematics Summer Research Program for Minorities.*

The National Research Experience for Undergraduate Programs (NREUP) is a rigorous summer mathematics research program for underrepresented undergraduate minorities supported by the Mathematical Association of America (MAA) and its Strengthening Unrepresented Minority Mathematics Achievement (SUMMA) program with funding being provided by the NSF and the NSA. The 6-week long session allows students first-hand experience at the process of mathematics research including the dissemination of their research through a conference or a journal. The NREUP has had the goal of increasing underrepresented minorities interest in obtaining advanced degrees and careers in mathematics or closely related field since its inception in summer of 2003. Also, 465 undergraduate students have participated in the program with 218 females. Of the 465 participants, 59% were African American, 23% were Hispanic Americans and 10% were Latino Americans with the remaining 8% consisted of Asian Americans, Pacific Islanders, American Indians and Middle Easterners. Each participant was requested to evaluate their program at its end and at one-, two- and four-year intervals. We will share the results of the NREUP evaluation along with our future plans for exploring other aspects of the NREUP. (Received September 17, 2013)

1096-J1-2310 **Lidia Gonzalez*** (lgonzalez@york.cuny.edu), York College, CUNY, Attention: Dr. Lidia Gonzalez, 94-20 Guy R Brewer Blvd., Jamaica, NY 11451. *Challenging the Under-representation of women in mathematics: The York Tensor Scholars Program.*

Research shows that not belonging is a prevalent theme among undergraduate students of mathematics (Solomon, 2007) especially members of underrepresented groups such as women who, because of social and historical realities, may struggle to build a mathematics identity (Walkerdine, 1998). Yet, supportive environments can counter such realities (Oswald & Harvey, 2001). The York Tensor Scholars Program, funded by the MAA and AAUW, is a mathematics circle for undergraduate students aiming to (1) increase the enthusiasm, confidence, and performance in mathematics of women (2) develop peer support and (3) challenge traditional perceptions of mathematicians while directing students to graduate programs/professions in mathematics. Students attend monthly talks given primarily by female mathematicians and later meet with the speaker in a social setting. I discuss the program and results from a research study exploring the effect of participation on students. Results show a broadening of students' definition of mathematics and while many students express an initial discomfort in attending social gatherings fearing they will have nothing in common with the mathematicians, results show a shift in such views for the better. (Received September 17, 2013)

1096-J1-2343 **Cristina Villalobos*** (mcvilla@utpa.edu), Department of Mathematics, University of Texas-Pan American, Edinburg, TX 78539, and **Olga Ramirez** and **Sakshi Puri**. *Integrating South Texas Efforts in STEM Education.* Preliminary report.

The Center of Excellence in STEM Education at the University of Texas-Pan American integrates South Texas efforts in the fields of science, technology, engineering, and mathematics. Its goals focus on strengthening STEM academic programs and in increasing the number of STEM graduates, particularly those from underrepresented groups, through activities focused on faculty professional development, the development of curricular materials in pre-college student outreach activities and undergraduate programs, undergraduate research, and the establishment of a student-faculty resource program. In this talk, the Center's activities will be discussed along with initiatives that inform, encourage, and retain students in the STEM fields and to pursue graduate studies. The Center is one of three centers funded externally over a four-year period. The University is a predominately Hispanic Serving Institution. (Received September 17, 2013)

1096-J1-2462 **Abdramane Serme*** (aserme@bmcc.cuny.edu), 199 Chambers Street, New York, NY 10007, and **Jean W. Richard** (jrichard@bmcc.cuny.edu), 199 Chambers Street, New York, NY 10007. *Redesigning Student Mentoring/Research Programs: From the Mentees Vantage Point.*

Almost 60% of the student population at BMCC (Borough of Manhattan Community College) are women and more than 70% of the student body are either Black or Hispanic. Student mentoring (by faculty member) programs have been a huge success in the mathematics department over the past few years. At BMCC, student mentoring/research programs are seen as an investment in the future of the new generation. As the "center of gravity" in higher education shifted away from traditional four-year college toward community college (Brock, 2010), student mentoring/research programs are being taken seriously and given an important role in the students educational learning at the community college level. It is well documented (Mervis, 2001), (Colley, 2003) that the number of students engaged in some type of research had risen across the country. It is also well known that students are very enthusiastic about mentoring programs (Mervis, 2001). The first goal of this presentation is to show how we were able to cultivate success so that other colleges may follow on that path to develop and run a strong and successful student mentoring/research program within their departments. The second goal of this presentation is to show the students' perspective of our mentoring programs. (Received September 17, 2013)

Projects, Demonstrations, and Activities that Engage Liberal Arts Mathematics Students

1096-J5-40 **Shawn J. Chiappetta*** (shawn.chiappetta@usiouxfalls.edu), University of Sioux Falls, Sioux Falls, SD 57105. *Creativity, Writing and Mathematics: The FancyPants Strip Pattern Portfolio.*

Students have an easy time identifying which rigid motions a given strip pattern contains, but have difficulty in how to create one of the seven types of strip patterns without overlapping another. This particular project engages students to tackle this problem by constructing their own strip patterns in the context of a creative works portfolio. The project also asks students to establish, as a written explanation, which rigid motions each submission incorporates and, as a last piece, give an explanation of the basic crystallography notation. Examples of student work will be exhibited. (Received June 10, 2013)

1096-J5-52 **Karen Holmes*** (kholmes@butler.edu). *Win, Lose, or Draw: An Analytical Reasoning Course at Butler University.*

Win, Lose, or Draw is a course created to fulfill the Analytical Reasoning requirement in the core at Butler University with the idea that the course would be student discovery based. To that end this course has a workbook with 26 group activities linking mathematics with games. Each class starts off explaining the day's activity and then, in groups of four, the students work together on the activity for the day. There are four days where lecture is the main part of the class, but the rest of the semester is group work. The math we do in class varies from logic puzzles, Venn diagrams, and combinatorics to conditional probability and independence. The talk will consist of several examples of group work from the workbook and will then focus mainly on the exercise Dice Games: Risk and Craps. (Received June 24, 2013)

1096-J5-120 **Raymond N Greenwell*** (matrng@hofstra.edu), Department of Mathematics, 103 Hofstra University, Hempstead, NY 11549, and **Daniel E Seabold**, Department of Mathematics, 103 Hofstra University, Hempstead, NY 11549. *The Stable Marriage Problem in the Classroom.*

The Gale-Shapley Stable Marriage Theorem is a fascinating result from 20th century mathematics that has practical applications to labor markets and school admissions and yet is accessible to students at the secondary and undergraduate level. We describe a classroom activity that demonstrates the Gale-Shapley algorithm through student participation. We will carry out the activity with the audience to show how we use this in a liberal arts mathematics class. (Received August 01, 2013)

1096-J5-256 **Thomas Q. Sibley*** (tsibley@csbsju.edu). *The Many Facets of Symmetry.*

Symmetry's wide reach and visual appeal provide a variety of ways to engage students in a liberal arts math course. I will discuss a few activities I regularly use, including students investigating mirrors, weaving patterns and color symmetry. One student favorite is the symmetry tour I give on my campus. Students are always amazed at the many examples of symmetry they have overlooked. (Received August 23, 2013)

1096-J5-326 **Karin R Saoub*** (saoub@roanoke.edu), 221 College Lane, Roanoke College, MCSP Department, Salem, VA 24153. *A Tour through Graph Theory: Projects for a Liberal Arts Math Course.*

How should a delivery service plan their route? How should a mailman most efficiently deliver the mail? While these questions seem the same, graph theoretically they are very different. These and other classic graph theory problems have been adapted for my liberal arts math course. We emphasize the basic strategies for solving small-sized problems, the challenges of abstracting to larger scales, and the importance of these challenges. Projects have students using real world data to answer questions about their local environment, from the Roanoke College campus to the greater Virginia area. This talk will highlight the Chinese Postman Problem, Traveling Salesman Problem and Shortest Network Problem and the activities associated with them. (Received August 28, 2013)

1096-J5-399 **Paul Taylor*** (pttaylor@ship.edu), Dept. of Mathematics, 1871 Old Main Dr., Shippensburg, PA 17257. *Two short projects for improving financial literacy.*

Financial literacy is a topic of great interest to most students, regardless of major or mathematical ability. The aim of these projects is to build some useful personal finance knowledge while developing an appreciation for the direct impact mathematics can have on our financial lives. In the first project compare the return on short term CDs to long term CDs after early withdrawal penalties. In the second we compute the returns on periodic investments (dollar cost averaging) through a stock market downturn. (Received September 02, 2013)

1096-J5-576 **Edmund A Lamagna*** (eal@cs.uri.edu), Dept of Computer Science and Statistics, University of Rhode Island, Kingston, RI 02881. *Puzzles + Games = Mathematical Thinking.*

Puzzles and games form the basis of a freshman seminar designed to develop mathematical and computational problem solving skills. The desired learning outcomes include: 1) helping students transition from high school to college, 2) motivating and creating excitement for the further study of mathematics, computer science, and other STEM subjects, 3) allowing students to work in small groups on fun, interesting problems, 4) introducing mathematical and computational problem solving strategies not typically encountered in high school or college, 5) instilling the confidence and persistence needed to solve complex, difficult problems, and 6) encouraging "out of the box" thinking and applying alternative problem solving strategies.

Each session begins by introducing a set of puzzles of a particular type or a game illustrating a particular principle. Students spend most of the period in small groups solving the puzzles or playing the game. Toward the end of class, students present and discuss their solutions with guidance from the instructor.

Topics include sequential movement, figurative numbers, proofs without words, probability, logic, number systems, algorithms, recursion, and graphs. Among the games played are Clue, Mastermind, and Ticket to Ride. (Received September 06, 2013)

1096-J5-1214 **Otis C. Wright, III*** (wrighto@cedarville.edu), Department of Science and Mathematics, 251 N. Main St., Cedarville, OH 45314. *Juggling as an Introduction to Mathematical Thinking.*

Simple juggling sequences provide an engaging demonstration of important aspects of mathematical thinking for liberal arts students with little or no background in rigorous mathematics. The process of modeling simple juggling patterns using periodic sequences of natural numbers illustrates the power of mathematical representation and logic to classify those periodic sequences which are actually jugglable. As a result of the juggling demonstration, students use principles of mathematical modeling such as abstraction, simplification and analysis. Students also learn about the mathematical concepts of sequences, periodicity, equivalence, classification and conditional sentences. (Received September 13, 2013)

1096-J5-1250 **Chester Ivan Ismay*** (ismayc@ripon.edu), 300 Seward Street, PO Box 248, Ripon, WI 54971. *Increasing Communication and Problem-Solving Skills in a Liberal Arts Probability Course.*

The liberal arts curriculum traditionally emphasizes the need for students to be strong, creative, critical thinkers able to convey ideas well both in written work and via oral communication. Meshing these notions with an upper level undergraduate mathematics course in probability while still ensuring coverage of many topics can be challenging. I will describe my attempts at avoiding the traditional lecture-based style of the course in order to improve student engagement and better meet these goals. My focus was on developing the course with students working together to solve problems during class sessions, writing their solutions individually using LaTeX, and working on individual research projects and group projects to further immerse themselves in the material and improve their communication skills. This type of course enables students to constantly work on tying these aspects of a liberal arts education with the challenge encountered with probability concepts such as Bayes' theorem, the central limit theorem, and multivariate distributions. (Received September 13, 2013)

1096-J5-1338 **Donna A. Dietz*** (dietz@american.edu). *Projective Geometry for the Liberal Arts Mathematics Class.*

Newly made popular by the Blue-Orange game of "Spot-it!" (where players try to find matching symbols on two arbitrary cards from a special deck), a unit on finite projective planes and associated affine planes is a perfect topic for undergraduate students. I will discuss learning objectives, classroom activities, and specific problems types which worked well (or failed) with my students in two classes. I also have written two Javascript applications which are online and free to be used in any teaching environment. (Received September 15, 2013)

1096-J5-1594 **Charles F. Rocca*** (roccac@wcsu.edu), 181 White Street, Western Connecticut State University, Department of Mathematics, Danbury, CT 06810. *An Exercise in the Philosophy of Mathematics.* Preliminary report.

In this session we will look at a writing assignment designed to encourage non-mathematics majors to explore philosophical questions in mathematics. Through videos, in class and out of class readings, and class discussions students in three different courses each designed for non-math/liberal arts majors develop their own answers to the three questions: What is mathematics?; What does it mean to do mathematics or to think mathematically?; Do we as humans invent or discover mathematics. (Received September 16, 2013)

1096-J5-1894 **Teresa E. Moore*** (moore@ithaca.edu), Department of Mathematics, 953 Danby Road, Ithaca College, Ithaca, NY 14850, and **L. Christine Kinsey** (kinsey@canisius.edu), Department of Mathematics & Statistics, Canisius College, Buffalo, NY 14208. *Kaleidoscopes in the liberal arts mathematics classroom.* Preliminary report.

We describe a series of activities we have used successfully in liberal arts mathematics courses at our institutions. We begin by experimenting with a single mirror and get the students to describe the effects of reflection of a planar figure, and then investigate successive reflections. We then move on to the effects generated by a hinged mirror and the students deduce the formula for the angles that allow for images that do not overlap. This introduces the idea of the group of symmetries of a regular polygon and the dihedral groups of even degree. The students find the Coxeter polygons and we construct kaleidoscopes using three mirrors arranged in a prism for each of these. The images in such kaleidoscopes allow us to introduce the idea of plane-filling tessellations generated by reflections. Other configurations of three mirrors can be used to extend these ideas to the symmetries of regular polyhedra. (Received September 16, 2013)

1096-J5-2039 **Debra L. Hydorn*** (dhydorn@umw.edu). *Infographics Activities to Promote Graphical and Quantitative Literacy.* Preliminary report.

Like many liberal arts schools, the General Education program at the University of Mary Washington includes the requirement that students take a first-year seminar. To take advantage of the use of infographics to display quantitative information across disciplines and the availability of new tools to create them, I created a first-year seminar to develop students' visual communication skills, both for reading and interpreting graphs and for creating their own. In this first year seminar students build core skills for visual analysis and learn about the cognitive, communication and aesthetic principles of information design. By examining collections of example infographics students develop an understanding of the components of effective infographics and construct a definition of visual literacy. In this presentation I will share a variety of class activities and projects from my infographics seminar that could be modified for use in other liberal arts mathematics courses. Example activities include "deconstructing" graphs, identifying the characteristics of effective infographics and calculating the "lie factor." I will also share infographics resources and some examples of students' work. (Received September 17, 2013)

1096-J5-2146 **Semra Kilic-Bahi*** (skilic-bahi@colby-sawyer.edu), 541 Main St., New London, NH 03257. *Civil Rights, Estimation, and Regression.*

This talk will focus on the integration of some major civil rights events into a quantitative reasoning class activity about regression. Through this activity, we learn to use spreadsheets, talk about the role of dependent and independent variables, scatter plots, regression lines, and correlation coefficients. (Received September 17, 2013)

1096-J5-2237 **Kurt Ludwick*** (keludwick@salisbury.edu), Salisbury University, 1101 Camden Ave, Salisbury, MD 21801. *Counting Melodies: A Musical Introduction to Recursion.* Preliminary report.

In this talk, I will present an activity that I have developed while teaching a course on connections between music and mathematics for a liberal arts audience. A significant portion of this course is devoted to the study of various types of counting problems. One such problem that arises is counting the number of distinct rhythms and melodies that can be written under certain restrictions. For example: "How many different n-beat rhythms can be written using only quarter notes and half notes?" leads us quickly to "discover" the Fibonacci sequence. Minor variations to this question - e.g., changing allowable note lengths, introducing rests, or allowing multiple pitches (thus, melodies rather than just rhythms) - motivates us, through fairly straightforward musical considerations, to explore a wide variety of recurrence relations. (Received September 17, 2013)

1096-J5-2316 **Darci L. Kracht*** (darci@math.kent.edu). *Adapting liberal arts mathematics hands-on activities to a large-lecture format.*

Kent State University offered a liberal arts mathematics course called Explorations in Modern Mathematics for many years in sections of 35 students. I developed hands-on activities for several of the topics in the course. These activities engaged the students and helped them to better understand the material. When budgetary constraints forced us to raise our class sizes to 100 students, I quit using these in-class activities. Then in Fall 2012, I tried a Rubik's cube unit in a large class. Emboldened by its success, I decided to use a hands-on activity involving Sicherman dice for a probability unit and a candy-dividing activity using the method of markers for a fair division unit in my Fall 2013 large-lecture classes. I will report on the degree of success of these attempts along with lessons learned. (Received September 17, 2013)

1096-J5-2370 **Cathy W. Grilli*** (cgrilli@cbu.edu), 650 East Parkway S., Memphis, TN 38104. *Walking the Line.*

An activity that I have found engages students in a Liberal Arts math class is using data collection devices and motion detectors. These exercises help students realize that functions are not items that mathematicians invented to torture them, but are a way to discuss occurrences in everyday life. A particular activity is to have students walk until they can produce different lines on the calculator. Of course, at each stage students are asked how they got the desired result and how this relates to slope. The relationship between speed, distance, and time is examined. With sufficient practice, ball tosses and drops can generate parabolas. Producing cooling curves show that exponential functions do exist outside of mathematics texts. Graphs can be transferred to paper for further analysis. While science majors may encounter instruments in labs that relate functions to their experiences outside of the classroom, liberal arts majors are less likely to do so. The talk will include the student instructions sheet so that the exercise can be taken into other classrooms. At the end of the semester, several students commented that these exercises were some of the best parts of the course. (Received September 17, 2013)

1096-J5-2443 **Colleen Duffy*** (duffycm@uwec.edu). *Engaging liberal arts students in mathematics.*
In this talk I will talk about strategies I use for engaging students in our "Introduction to Mathematical Thinking" and "Mathematics in Latin American Cultures" courses, the former of which I refer to as "Math is fun." My goal is for all of my students to see mathematics in a (positive) new light and to stretch their abstract thinking skills. I cover topics such as infinity, mathematical paradoxes, fractals, music, art, and Maya and Inca mathematics. I use a story-telling context of traveling to various places, such as Paradox City. In the stories the students meet different mathematicians and discuss abstract mathematical concepts; it is a discussion and project based course. I will describe my teaching model, give examples, and mention ways in which another faculty member could develop similar courses. (Received September 17, 2013)

1096-J5-2490 **Teena Carroll*** (ccarroll@ehc.edu). *Venn Diagram Bingo and other Games for Liberal Arts Math Classes.*
Incorporating content knowledge into games is a great way to learn and have fun at the same time. Liberal arts math classes are a perfect place to play games like Venn diagram Bingo, with blank Venn diagrams to fill and zany objects to place inside the regions, Let's Make a Deal to study expectation, and Plinko from the Price is Right to study normal curves. (Received September 17, 2013)

1096-J5-2497 **M. Reba*** (mreba@clemson.edu) and **D. Shier**. *Using Graph Representations to Solve Puzzles.*
Using graphs to solve puzzles not only introduces students to the benefits of using alternative representations in problem-solving, but also motivates their interest in the pervasiveness of graphical structures found in modern transportation, communication, and computer networks. We present activities where solutions to mazes, jug-pouring problems, chip-stacking puzzles, and word puzzles can be revealed by finding paths or colorings in certain graphs. Activities like these are part of in-class group work and individual homework. They encourage students to be creative and many have incorporated these ideas into final classroom projects. (Received September 17, 2013)

1096-J5-2609 **Sharon M Frechette*** (sfrechet@mathcs.holycross.edu), Dept. of Mathematics and Computer Science, College of the Holy Cross, 1 College Street, Worcester, MA 01610. *Engaging first-year students in the mathematics of cryptology: "Ciphers and Heroes".*
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 year-long seminar focusing on a specific discipline, yet heavily emphasizing writing, discussion, and collaborative activities. This fall, I am teaching Ciphers and Heroes, a seminar on historical ciphers up through World War II. In the spring we'll study modern ciphers and authentication protocols in a second seminar, Privacy in the Internet Age. The mathematical content of these courses was once part of an intense one-semester topics course for non-majors. Spreading this across a full year allowed the algebra and number theory background to be introduced more collaboratively. It also gave flexibility in creating activities and choosing readings to engage students in the culture of cryptology as well as the math. From understanding 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 math to other areas of the curriculum. In this talk, I will discuss several student activities from the fall course, such as learning the Enigma workings by hand using Michael Koss' Paper Enigma. (Received September 17, 2013)

1096-J5-2631 **Tammy Muhs*** (tammy.muhs@ucf.edu), Department of Mathematics, University of Central Florida, 4393 Andromeda Loop N, Orlando, FL 32816-1364. *Students Discover Math in the World Around Them: The Use of Projects in a Liberal Arts Mathematics Course.*
Students enrolled in the University of Central Florida's Explorations in Mathematics course explore the beauty and utility of mathematics including symmetry, voting strategies, finance, networks, paths and circuits, as well as finding the mathematical connections with music, art, architecture, and nature. Upon successful completion of the course, the student should be able to reason critically, think creatively, assess evidence from conclusions, and use skills in abstract and quantitative thinking.

As the theme of the course is "mathematics is everywhere", students complete a culminating project in which they find the mathematics in something that is a major part of their life or source of enjoyment. This results in a plethora of interdisciplinary projects including artistic creations, musical compositions, mathematical poetry, short stories, mock elections, hospitality event planning, virtual travel, educational lesson plans, etc.

This presentation will include information on the project requirements for both small classes of 49 students, as well as large classes of 200 or more students, evaluation criteria for peer reviews and instructor evaluations, student reactions, and lessons learned. (Received September 17, 2013)

Putting a Theme in a History of Mathematics Course

1096-K1-51 **Thomas Drucker*** (druckert@uww.edu), Dept. of Mathematical and Computer Sciences, University of Wisconsin–Whitewater, Whitewater, WI 53190. *Return to Infinity in the History of Mathematics Classroom.*

At a session at MathFest in Lexington in 2011 the plan of using infinity as an organizing theme for a course in history of mathematics for elementary education majors was presented. Since then the plan has been put into practice and data gathered to serve as the basis for a comparison with the more common chronological organizational principle. The advantages of using infinity as a theme can run up against some obstacles in the classroom, but a comparison with some other possible themes works to the advantage of infinity, partly because of its endless connections with other disciplines. (Received June 19, 2013)

1096-K1-331 **James T Smith*** (smith@sfsu.edu), 1363 27th Avenue, San Francisco, CA 94122. *Giuseppe Peano and Writing in a History Course.*

Around 2003 I switched to history of mathematics, and taught that course three times. It was aimed at junior math. majors, with a calculus prerequisite. I lectured from Struik's text and one other. The course had two themes: Giuseppe Peano and Writing History. Almost the entire grade was based on two substantial term papers: topics were chosen by the students with my permission. I will discuss why I chose Peano and how I used his biography, and how and why I implemented the emphasis on writing. Although students' preparation declined over four years, the quality of their work increased. The 2009 course was the best I ever taught. (Received August 28, 2013)

1096-K1-534 **Emelie A. Kenney*** (kenney@siena.edu), Department of Mathematics, Siena College, 515 Loudon Road, Loudonville, NY 12211. *HoM Courses to Inspire Liberal Arts Majors (and Others): A Menu of Eleven Organizing Themes.* Preliminary report.

An undergraduate history of mathematics course that is not designed specifically for majors naturally presents seemingly insurmountable challenges for the course designer. In particular, it is difficult to discuss the history of a subject with someone who is mostly unfamiliar with the subject. To circumvent this problem, it is possible to organize course content around one or more themes so that students actually get to do mathematics, rather than solely read about what others have done. Of course, depending on specific topics chosen, depth of discussion, and so on, most of these themes could generate a course entirely suitable for mathematics majors, as well.

Here, I present several ideas for organizing themes, with special emphasis on three of them, which are as follows: (1) Euler's identity, and e, i, pi, 1, and 0; (2) Three Centers of Mathematics in the Ancient World: Plato's Academy, The Library at Alexandria, and Baghdad's House of Wisdom; and (3) Mathematical Culture and Its Role in Promoting the Development of Mathematics: Schools of Thought, Journals, Societies, Congresses, Institutions, and Correspondence. (Received September 05, 2013)

1096-K1-1254 **Satish C Bhatnagar*** (bhatnaga@unlv.nevada.edu). *New approaches in History of Mathematics courses.*

The paper delineates two new approaches for history of mathematics courses. This fall, I took a frog-leap approach in the timeline of history of mathematics. For example, in the first week, a standard 1st chapter on prehistoric math was followed by the 24th chapter on history of the latest mathematics problems in the second week – and then switching back to 2nd, and so on. This type of coverage suits math graduate students as they can appreciate a 'candle burning at both ends'. Secondly, in order to instill a historian's mindset in mathematics students, 'small' hands-on-history projects are done. These individual projects are of the nature that one cannot find information on them by Googling or browsing in the libraries. A typical project requires both leg work and finger work in collecting oral history, doing interviews, visiting offices, museums, and special collections. The paper describes some projects. At the end, the students get an unforgettable experience on 'the facts' in history and how they are different from proofs in mathematics (Received September 14, 2013)

1096-K1-1884 **Diana White*** (diana.white@ucdenver.edu). *A History of Math Class Centered Around the Development of Number, Operation, and Solving Equations.*

The history of mathematics is a vast subject spanning millennia, yet often "covered" in at most one undergraduate mathematics course. This leads to a variety of choices for instructors, to include breath versus depth and survey versus thematic approaches. In this talk, we provide a general overview of a one-semester course centered around the concepts of number, operation, and solving equations. We provide background on the rationale for these choices, to include why the instructor thinks they are a good choice for general mathematics majors as well as those preparing to become K12 teachers. (Received September 16, 2013)

1096-K1-1932 **Dorothee Jane Blum*** (dorothee.blum@millersville.edu), Department of Mathematics, P. O. Box 1002, Millersville University, Millersville, PA 17551-0302. *Bringing together "older" and "newer" mathematics.*

The History of Mathematics course at Millersville University is designated as a "perspectives" (P) course and as such it is only allowed to have one mathematics prerequisite. The most useful choice was Calculus I. Also specific objectives must be addressed by every P course. At Millersville, all students must satisfy the "perspectives" requirement as part of the general education program and every semester about 30 students in a variety of majors with varying backgrounds in mathematics choose to do this by taking History of Mathematics. Having taught this course for more than ten years to this broad audience, I have developed a specific theme that helps me organize the ideas I hope students will take with them from this course as part of their general education. The overall theme is linear, but for many topics, especially those that are encountered early in the course, we explore how later mathematicians studied these same topics, expanding on them and often solving previously unsolved problems. This brings together the "old" and the "new" and emphasizes the growth of mathematics, the inquisitiveness of mathematicians, the persistence of mathematicians, and sometimes even the relevance of mathematics. (Received September 16, 2013)

1096-K1-2419 **Joseph P. Brennan*** (joseph.brennan@ucf.edu), Department of Mathematics, University of Central Florida, 4393 Andromeda Loop N, Orlando, FL 32816-1364. *A web journey through the history of mathematics: two approaches Part I.*

The history of mathematics course at the University of Central Florida was offered as a web course for the first time in the Fall semester of 2012.

The elimination of course lectures demanded a redesign of the class to incorporate primary and secondary reading and assessments to direct the student to an understanding of mathematics as an important element in the intellectual history of humankind.

This presentation will examine the issues of the design, decisions related to the course focus, and lessons learned. (Received September 17, 2013)

1096-K1-2500 **Tammy Muhs*** (tammy.muhs@ucf.edu), Department of Mathematics, University of Central Florida, 4393 Andromeda Loop N, Orlando, FL 32816-1364. *A Web Journey Through the History of Mathematics: Two Approaches Part II.*

University of Central Florida's history of mathematics course was adapted to be a web course in fall 2012. The web course was offered for a second time during the fall 2013 semester with a different faculty member assigned to teach the course.

The course was modified based on lessons learned from the initial offering, as well as to accommodate differences in teaching styles.

The history of mathematics course is a required course for all math education majors at the University of Central Florida. This resulted in 90% of the students enrolled in the course having math education as their declared major. An attempt to modify content to address student demographics was made.

This presentation will examine the differences in course focus and assessment between the two semesters as well as lessons learned. (Received September 17, 2013)

1096-K1-2568 **Alex M McAllister*** (alex.mcallister@centre.edu), Mathematics Department, Centre College, Danville, KY 40422. *Mathematical Impossibilities.*

This presentation discusses history of mathematics courses themed around "mathematical impossibilities;" namely, mathematically unsolvable questions and unprovable claims that do not have answers of the expected form. Such impossibilities will in some sense never be answered because mathematicians have proven that the hoped for answers simply do not exist. Topics in these courses have included non-Euclidean geometries, the insolvability of the quintic, geometric constructions, the Gödel incompleteness theorems, the continuum hypothesis, and the halting problem, as well as the history, people, and various consequences of these results. We discuss renditions of this course for majors, for freshman in first-year seminar, and for a diverse collection of students during a study abroad course in Greece. (Received September 17, 2013)

Reinventing the Calculus Sequence

1096-K5-173 **Daniel J Velleman*** (djvelleman@amherst.edu), Department of Mathematics, Amherst College, Amherst, MA 01002. *New Approaches to Some Topics in Calculus.* Preliminary report.

I will discuss new approaches to the presentation of several topics in the standard calculus curriculum. Topics to be discussed include limits of compositions of functions, integration by substitution, and paradoxes in calculus. (Received August 13, 2013)

1096-K5-192 **Matthew E Cathey*** (catheyme@wofford.edu), Dept. of Mathematics, 429 N Church St, Spartanburg, SC 29303, and **Joseph A. Spivey** (spiveyja@wofford.edu), Dept. of Mathematics, 429 N Church St, Spartanburg, SC 29303. *Addressing the AP Calculus Problem at a SLAC: An Integrated Approach.*

Wofford College, a 4-year liberal arts college with around 1500 students, faced particular challenges in its first-year calculus sequence: the semesters are 13 weeks long, and each class meets for only 2.5 hours each week. Using the standard calculus curriculum meant only differential calculus could be covered in the first semester, leaving integral calculus for the second. Students taking only Calculus I weren't seeing the whole picture, and students with AP credit for one semester were bored with much of our second semester, and missed the rigor of the ϵ-δ formulation of limits. In 2011, Drs. Matt Cathey and Joseph Spivey completely redesigned the two-semester curriculum, presenting differentiation and antidifferentiation techniques side-by-side in the first semester, and postponing formal definitions and theorem proofs to the second. Data reflecting the success of this restructuring will be reported. (Received August 15, 2013)

1096-K5-647 **Heather A. Lewis*** (hlewis5@naz.edu), Nazareth College, 4245 East Avenue, Rochester, NY 14618. *Moving Multivariable topics to Calculus II: Does it work?* Preliminary report.

In 2012, our department overhauled the order in which we taught topics in calculus. In particular, we moved most of multivariable calculus – including extended treatment of partial derivatives and multiple integration – to Calculus II, a course which starts with basic single integration techniques. This solved a few problems (the flow of the material, the benefit for other majors) and created a few others (course sequencing for transfer students, the loss of some traditional topics), but overall appears to be a success. In this talk I will present the specific challenges and benefits that arose as a result. (Received September 08, 2013)

1096-K5-1673 **Nicholas Baeth*** (baeth@ucmo.edu), W.C. Morris 213, UCM, Warrensburg, MO 64093. *Resequencing Calculus — An early multivariate approach.* Preliminary report.

Calculus at the University of Central Missouri has, for decades, been taught in "the standard order" beginning with limits, and then progressing to derivatives, antiderivatives, sequences and series, and finally on to multivariate topics. Although this has generally worked well at UCM, a regional comprehensive state university with roughly 11,000 students, there have always been certain downsides to saving multivariate topics until the third semester. Thus the Department of Mathematics and Computer Science was pleased to be asked to pilot a restructuring of the calculus sequence as part of a Phase 2 NSF TUES Type 2 Grant (no. 122556) coordinated by the University of Evansville. In this talk I will briefly give an overview of UCM, our students, and the traditional calculus sequence. I will then discuss the pros and cons of our current system as experienced by both students and faculty and the expected benefits and downsides of restructuring the sequence to allow for an earlier introduction of multivariate topics. Finally, I will share our experiences having completed the first semester (calculus 1 only) of the restructured pilot. (Received September 16, 2013)

1096-K5-1679 **William T. Mahavier*** (ted.mahavier@lamar.edu). *How about a free set of IBL Calculus notes that covers all of Calculus I, II and III?*

Calculus is fertile recruiting ground for mathematics majors, although far too many calculus courses treat the subject as a set of rules and techniques to master. In my experience, those who enjoy such rote work often turn out to be poor majors and those who have the potential to be mathematicians are often turned away by such an approach. We discuss a set of calculus notes that began as an NSF project more than a decade ago. These may well be the only set of notes that are freely available, problem-based (IBL) and cover all of Calculus I, II and III. (Received September 16, 2013)

1096-K5-1742 **Martin E Flashman*** (flashman@humboldt.edu). *Making Sense of Series and Sequences in The First Calculus Course.* Preliminary report.

In most calculus texts and courses, the treatment of series and in particular Taylor series and applications (to integration and differential equations) usually follow a lengthy introduction through sequences. The author will present a more motivated and sensible approach he has used that refocuses attention on three basic themes for the entire course: estimation, differential equations, and modelling. (Received September 16, 2013)

1096-K5-2241 **Vincent J. Matsko*** (vince.matsko@gmail.com), 19 Lambert Dr., Princeton, NJ 08540. *Reshuffling Calculus.*

Most calculus textbooks follow a traditional approach to introducing the idea of differentiation – first discuss limits, then the definition of the derivative. Alternatively, the derivative may be defined first as a motivation for studying limits. It is easy to calculate the derivative of a polynomial without a sophisticated knowledge of limits. With this prompt, students may then be asked to differentiate several other common functions, in the course of which many of the limits usually encountered in a preparatory chapter are in fact developed by the students themselves (rather than studied now because they'll be used later). This is just one example of when reshuffling the order sections are covered in a calculus sequence may enhance student learning. (Received September 17, 2013)

1096-K5-2616 **Daniel T Kaplan*** (kaplan@macalester.edu), Mathematics, Statistics, and Comp. Sci., Macalester College, 1600 Grand Ave., Saint Paul, MN 55105. *Modeling Calculus.*

At Macalester, we've reinvented our calculus sequence around modeling. In short, we've asked what calculus concepts and techniques are most important for constructing and interpreting models. The answers involve some of the traditional topics (derivatives, integrals but not elaborate techniques for doing these algebraically), approximation to data, linear algebra, and differential equations: topics that come directly from the MAA CRAFTY reports. Recognizing that most students take at most one semester of calculus, we organize these topics in a way that can be effectively handled in one semester. In addition to presenting the first-semester course topics and a complete set of course materials and (free) software, I'll describe how the creation of this first-semester calculus course has freed us to redesign the follow-up courses, both in calculus and statistics. (Received September 17, 2013)

Research on the Teaching and Learning of Undergraduate Mathematics

1096-L1-291 **Jessica Ellis*** (ellis3@rohan.sdsu.edu). *Graduate students Teaching Assistants' (GTAs') beliefs, instructional practices, and student success.*

In this report I present findings from a large, national study focused on Calculus I instruction. Graduate student Teaching Assistants (GTAs) contribute to Calculus I instruction in two ways: as the primary teacher and as recitation leaders. As teachers, GTAs are completely in charge of the course just as a lecturer or tenured track/ tenured faculty would be, although they lack the experience, education, or time commitment of their faculty counterparts. In this study, I investigate how GTAs compare to tenure track/tenured faculty, and other full/part time faculty on their (a) beliefs about mathematics; (b) instructional practices; and (c) students' success in Calculus I. Findings from this report point clearly to a need to prepare GTAs adequately for the teaching of calculus but also for further examination of the nature and implications of the differences between GTA and other instructor types' beliefs about teaching and teaching practices. (Received August 26, 2013)

1096-L1-364 **MINSU KIM*** (minsu.kim@ung.edu), Oakwood, GA 30566. *The effectiveness of 5 minute preview video lectures using Smart Board, Camtasia Studio, and Podcasting on mathematical achievement and mathematics self-efficacy.*

The purpose of this study is to examine the effectiveness of 5 minute preview video lectures for each lecture using podcasting in terms of mathematical achievement and mathematics self-efficacy in intermediate algebra and college algebra courses at a university. Data from 128 students in six sections was collected for two semesters through first and final exams, questionnaires, classroom observation checklist, and the Mathematics Self-Efficacy Scale. The findings indicate no significant difference on the mathematical achievement and mathematics self-efficacy between the control group who did not watch the preview lectures and the treatment group who watched the preview lectures while the treatment group slightly developed their mathematics self-efficacy and abilities for mobile technology. In addition, the treatment group was significantly satisfied with the preview lectures. When the treatment group was divided into intermediate low and high subgroups based on the first exam, the intermediate low subgroup significantly improved their mathematical achievement. (Received August 30, 2013)

1096-L1-529 **Spencer Bagley*** (sbagley@rohan.sdsu.edu). *A Comparison of Four Pedagogical Strategies in Calculus.*

The quality of education in introductory calculus classes is an issue of particular educational and economic importance. In work related to a national study of college calculus programs conducted under the aegis of the MAA, I report on a study of four different pedagogical approaches to Calculus I at a single institution in the Fall 2012 semester. Using statistical methods, I analyze the effects of these four approaches on students' persistence in STEM major tracks, attitudes and beliefs about mathematics, and procedural and conceptual achievement in calculus. Using qualitative methods, I draw links from the statistical results to differences and commonalities in the four classroom strategies. (Received September 05, 2013)

1096-L1-913 **Daniel Lee Reinholz*** (reinholz@berkeley.edu). *Promoting Calculus Understanding Through Explanation and Reflection.*

This presentation draws on my dissertation study of learning in introductory college calculus. During the course of a two semesters of experimental intervention, students engaged with a variety activities designed to promote explanation and reflection. The core of the design was an activity called peer-assisted reflection (PAR). The purpose of PAR was to have students: (1) engage in meaningful problems, (2) reflect on their own work, (3) reflect on a peer's work and give/receive peer-feedback, and finally (4) revise their work based on insights gained throughout this cycle. Students in the experimental sections had considerably improved success rates (13% during phase I) and (23% during phase II) compared to other sections of the course. Students also had notable improvements in exam scores (up to 15% on common midterms). Finally, students in the experimental sections had considerably improved explanation abilities and developed productive dispositions towards learning mathematics. In this presentation I will provide an overview of the design, an analysis of student growth, and a discussion of theoretical insights. (Received September 11, 2013)

1096-L1-1096 **Harrison E. Stalvey*** (hstalvey1@gsu.edu), **Draga Vidakovic** and **Mariana Montiel**. *Developing the Notion of Function Between Sets of Equivalence Classes from the APOS Perspective.* Preliminary report.

A substantial amount of research has explored students' general understanding of the concept of function, but a limited amount of literature exists on how students cope in contexts in which the domain and range are sets of objects that are not single numbers. Here, we report on how mathematics students who are transitioning to advanced mathematics courses might cognitively develop the notion of function between sets of equivalence classes, particularly in the context of $\mathbb{Z}_n$. Using APOS theory as our theoretical framework, we analyze empirical data to determine the possible mental constructions that are involved in understanding the notion of 'well-defined'. We conclude with a genetic decomposition, or a summary of the mental constructions, based on our analysis. (Received September 12, 2013)

1096-L1-1302 **Kelly M. Bubp*** (bubp@ohio.edu) and **Michael A. Smith**. *A Unified Framework for Argumentation and Proof.*

Argumentation and proof are intertwined essentials of the creation and validation of mathematics. Mathematicians use intuitive, informal, and formal reasoning during the processes of developing, testing, refining, and proving conjectures. However, instruction in proof typically presents proving as a linear, formal process devoid of argumentation. In this presentation, we will introduce a framework that identifies key skills, understandings, and activities for developing students' competence in argumentation and proof. This framework can be used as a basis for curriculum design and evaluation, a tool for classroom observation, and a foundation for research on argumentation and proof. (Received September 17, 2013)

1096-L1-1413 **Jennifer Yantz*** (jennifer.yantz@mtsu.edu). *Investigating the Links between Students' Knowledge of Rational Numbers and Algebraic Procedures and Students' Success in Undergraduate Mathematics.*

Undergraduate students must have well-developed algebraic procedural knowledge in order to succeed in calculus and other advanced mathematics courses (Baranchik & Cherkas, 2002 and Tall, 1993). Instructors report that many common algebra errors made by undergraduate students are related to simplifying and performing operations with rational expressions (Dawkins, n.d.; Schechter, 2009 and Scofield, 2003). Hiebert and Wearne (2003) submitted that operations with algebraic rational expressions should just be an extension of a students' understanding of operations with rational numbers. Using Hiebert and Carpenter's (1992) theory of connected representations as a framework, this study explored the connections students made, if any, between algebraic and numeric rational expressions. An assessment with three pairs of closely matched algebraic and numeric problems was given to 107 undergraduate students in five randomly selected sections of precalculus. The main focus of this presentation will be the qualitative analysis of the students' strategies used to solve the problems and the patterns of errors that emerged. I will discuss the evidence of students' lack of understanding of fundamental mathematical ideas and the implications for mathematics education. (Received September 15, 2013)

1096-L1-1566 **Robert Talbert*** (talbertr@gvsu.edu), Department of Mathematics, Grand Valley State University, 1 Campus Drive, Allendale, MI 49401. *Inverting the transition-to-proof course.* Preliminary report.

In this talk, we examine the results of employing an inverted or "flipped" class design in a transition-to-proof course for second- and third-year mathematics majors. We briefly review the extant research on transition-to-proof courses and focus particularly on Pintrich's framework of self-regulated learning as a means of understanding student difficulties in such courses. Then we will overview the inverted classroom model of course design and its potential benefits in transition-to-proof courses. Finally, results from the redesign of a transition-to-proof class at the author's university are given and discussed. (Received September 16, 2013)

1096-L1-1650 **Misun Lee*** (mi.s.lee-2@ou.edu), Dept. of Math, University of Oklahoma, Norman, OK 73019. *Calculus Instructors' Resources, Orientations and Goals in Teaching Low Achieving Students.*

Teaching and learning calculus has been the subject of mathematics education research for many years. Many research noted that calculus is acting as a filter to keep students from pursuing their fields of interest. The aim of this report is to explore the instructors' resources, orientations and goals in teaching calculus to low achieving students using Schoefeld's ROG framework. The results of the interviews show that although the professors thought differently about many aspects regarding teaching calculus, they all claimed that the first step to succeed in calculus courses is being prepared and having the right background. (Received September 16, 2013)

1096-L1-1775 **Megan Wawro*** (mwawro@vt.edu) and **David Plaxco** (dplaxco@vt.edu). *Analyzing student understanding in linear algebra through mathematical activity.*

The purpose of this study is to characterize students' conceptions of span and linear (in)dependence. The data under consideration are portions of individual interviews with linear algebra students, and grounded analysis revealed a wide range of student conceptions of span and linear (in)dependence. The authors organized these conceptions into four categories: travel, geometric, vector algebraic, and matrix algebraic. To further illuminate participants' conceptions of span and linear (in)dependence, the authors developed a framework to classify the participants' engagement into five types of mathematical activity: defining, proving, relating, example generating, and problem solving. This framework proves useful in providing finer-grained analyses of students' conceptions and the potential value and/or limitations of such conceptions in certain contexts. (Received September 16, 2013)

1096-L1-1954 **Laurel A Cooley** (lcooley@brooklyn.cuny.edu), Mathematics Department, Brooklyn College, CUNY, Brooklyn, NY 11210, **William O Martin*** (william.martin@ndsu.edu), Department of Mathematics, North Dakota State University, Fargo, ND 58108, and **Draga Vidakovic** (dvidakovic@gsu.edu), Department of Mathematics and Statistics, Georgia State University, Atlanta, GA 30303. *An Investigation of Student Perceptions of Linear Algebra Modules.*

In this report we examine students' perceptions of the implementation of carefully designed curriculum materials (called modules) in linear algebra courses at three different universities. The curricular materials were produced collaboratively by STEM and mathematics education faculty as members of a professional learning community (PLC) over several years. We have described the development and implementation of these materials elsewhere. Our focus here is on more detailed analysis of comments that student participants made in response to survey questions about the impact on their engagement, perceived learning, self-confidence, and notions of the broader nature of mathematics.

The Linear algebra In New Environments (LINE) project—partially supported by the National Science Foundation —was designed to promote a reflective, collaborative culture of teaching and learning among STEM discipline faculty. The project integrates (a) the study of important mathematical content, (b) the use of applications, and (c) reflection on mathematical learning theories by faculty and students in the context of an advanced undergraduate linear algebra course. (Received September 16, 2013)

1096-L1-2075 **Gregory M Johnson** (greggo@math.cmu.edu), Department of Mathematics, Wean Hall 6113, Carnegie Mellon University, Pittsburgh, PA 15213, **Hunter R Johnson** (hujohnson@jjay.cuny.edu), Mathematics and Computer Science Dept., John Jay College, CUNY, New York, NY 10019, and **Christopher S Shaw*** (cshaw@colum.edu), Dept. of Science & Mathematics, Columbia College Chicago, 600 S. Michigan Ave, Chicago, IL 60605. *Does inherent Platonism predict strength in abstract mathematics?* Preliminary report.

Broadly construed, Platonism is a philosophical understanding of abstract mathematical objects as existing in a plane outside the tangible world. This stands in contrast with the view that mathematical concepts exist only insofar as they are used to describe worldly objects. While the philosophical details may be esoteric, the authors believe it is reasonable to make a basic assessment of one's place on the Platonist continuum through a short series of directed questions.

In this study, the investigators used a short anonymous survey with a group of student volunteers who have completed courses in the calculus sequence, and plan to analyze the relationship, if any, between their place on the continuum and their success in the course. The investigators hope these research findings will help to determine whether it may be prescriptive to address philosophical questions in early mathematical coursework in order improve performance in advanced mathematics courses. (Received September 17, 2013)

1096-L1-2128 **Michael A. Smith*** (ms114409@ohio.edu) and **Kelly M. Bubp** (bubp@ohio.edu). *An Evaluation of Argumentation and Proof Opportunities in Transition-to-Proof Textbooks.* Preliminary report.

One of the key goals of undergraduate mathematics education is the development of students' competencies in argumentation and proof. In this talk, we will discuss our evaluation of eight curricula developed for transition-to-proof courses with respect to the opportunities they provide for students to engage in argumentation and proving. For this evaluation, we use a framework built on the premise that argumentation and proof are essential to the creation and validation of mathematics. Thus, curricula that engage students in a full range of argumentation and proof activities should offer students the strongest possible foundation for becoming professional mathematicians. (Received September 17, 2013)

1096-L1-2332 **John Paul Cook***, jpcook@usao.edu. *The Emergence of Algebraic Structure: Students Come to Understand Units and Zero-divisors.*

Little is known about how students learn the basic ideas of ring theory. While the literature addressing student learning of group theory is certainly relevant, the concepts of zero-divisor and, more generally, elements with no multiplicative inverse are among those for which group theory has no analog. In order to better understand how students come to understand the concepts of unit and zero-divisor, this talk presents results from a study that investigated how students can capitalize on their intuitive notions of solving equations to reinvent the definitions of ring, integral domain, and field. Particular focus is placed on the emergence and progressive formalization of the concept of zero-divisor at various stages of the reinvention process. Findings include a conceptual framework characterizing the emergence of the concept of zero-divisor and unit. This framework, in addition to documenting the emergence of these concepts, suggests that these concepts arise in direct contrast to each other. (Received September 17, 2013)

1096-L1-2380 **Timothy C Boester*** (timothy.boester@wright.edu). *Relating Delta and Epsilon: How Students Graphically Create an Understanding of the Formal Definition of Limit at a Point.* Preliminary report.

Different theories of how students come to conceptualize the formal definition of limit at a point have all broken apart the monolithic definition into conceptual pieces. This preliminary report will explore how students graphically relate delta and epsilon intervals. After a classroom activity introducing the formal definition, undergraduates were asked to complete a series of graphical diagrams in order to judge the appropriateness of delta-epsilon pairings in an interview setting. The talk will describe how students completed these diagrams, and how the choices students made when judging the pairings correlate with their understanding of the conceptual pieces of the formal definition of limit at a point. (Received September 17, 2013)

1096-L1-2538 **Milos Savic*** (savic@ou.edu) and **Gulden Karakok** (gulden.karakok@unco.edu). *How can we (or should we) assess undergraduate students' creativity?* Preliminary report.

As our assessment tools mostly focus on accuracy and procedural fluency, emphasis on problem-solving skills and inquiry-based approaches require different evaluation methods. To capitalize on students' natural curiosity and enthusiasm might require explicitly valuing their own creative processes in solving problems. In this presentation, we will discuss various definitions of creativity that expert mathematicians expect students to demonstrate in proof writing and problem solving. We will also share one possible rubric, modified by the mathematicians interviewed, to evaluate students' creativity in such processes. (Received September 17, 2013)

1096-L1-2592 **Kathleen M Clark*** (kclark@fsu.edu), 1114 West Call Street, School of Teacher Education, Tallahassee, FL 32306-4459. *The contributions of a history and philosophy of mathematics course on undergraduate students' mathematical thinking.* Preliminary report.

In this preliminary report I present initial findings from a research study conducted in 2012 in which the contributions of a history and philosophy of mathematics course on the mathematical knowledge of undergraduate students were investigated. The primary research question was: In what ways does the study of the history and philosophy of mathematics change undergraduate students' mathematical thinking about "essential" mathematics concepts? Although research exists that describes how history of mathematics contributes to the development of mathematical knowledge for teaching, it is also of interest to examine the potential impact of a history of mathematics course on the more general undergraduate population. The present study employed mathematical task interviews with four participants (two mathematics majors, two non-mathematics majors), both pre- and post-instruction, on the topics of the complex number system, the concept of infinity, and the axiomatic structure of mathematics. Initial analyses indicate positive impacts on the students' mathematical knowledge and that comparisons among different undergraduate majors may reveal opportunities for future research. (Received September 17, 2013)

1096-L1-2618 **John Paul Cook**, jpcook@usao.edu, **Brian Katz***, briankatz@augustana.edu, and **Milos Savic**, savic@math.ou.edu. *Developing Reinvention Materials in Ring Theory: Analysis of Students' Mathematical Activity.* Preliminary report.

In recent years, the method of guided reinvention supported the creation of innovative, research-based instructional materials for courses at the undergraduate level, including calculus, geometry, differential equations, linear algebra, and group theory. This project, consisting of a sequence of a small-scale and a full-classroom teaching experiment, seeks to extend one such instructional trajectory that promotes students' reinvention of definitions from introductory ring theory. In this talk, we will discuss results from the teaching experiments related to students' understanding of particular ring-theoretic concepts, and how we sought to leverage their reasoning through the creation of instructional tasks. (Received September 17, 2013)

1096-L1-2705 **Joanna Mamona-Downs*** (mamona@upatras.gr), 323 E Veterans Way, Tempe, AZ 85281. *On the reconciliation of different non-equivalent definitions designed for the same concept, in the context of limits for two-variable functions.*

Two definitions are considered for the limit at a point P of a function mapping (a subset of) the real plane into the real numbers. For the first, convergence at P is determined by establishing that for any real interval centred at the proposed limit, a disc centred at P (lacking P) is mapped into that interval. For the second, convergence at the point P is determined by the existence and consistency of the limits at P over all half-lines emanating from P. Educational issues that arise are: Geometric interpretation of the limiting processes; parameterization (to utilize the definition of a limit for the one-variable case); grounds to prefer one definition over another; what it does mean for definitions to be equivalent; would students consider and determine that the two definitions above are not equivalent? I will present a teaching sequence guiding students to adapt the second definition to become equivalent to the first. For this, the notion of the 'greatest' δ given a particular ϵ for 1-variable functions is required; this notion is modeled in terms of sets as the 'greatest' δ may not exist (so suprema come in). (Received September 18, 2013)

Scholarship of Teaching and Learning in Collegiate Mathematics

1096-L5-126 **Marilyn Reba*** (mreba@clemson.edu) and **Meredith Burr**. *Investigating Student Learning in a Hybrid Calculus I.*

Hybrid formats of college courses replace a portion of classroom time with time online. The hybrid format offers students flexibility in scheduling (fewer hours on campus), and offers the university help with space-management issues. A hybrid format may also result in students who come to class better prepared for work on more difficult topics. Does a hybrid format of Calculus I improve student learning? In Spring 2013 and Fall 2014, we transformed 5 sections of Calculus I, a four credit-hour on-campus course, into a hybrid course in which one of these four credit-hours is online. The hybrid course content is identical to the non-hybrid course, but some concepts are introduced via instructor-created video lectures posted on Blackboard and via other online resources such as interactive apps. Students watch these lectures and submit related Online-Lecture Worksheets when they come to class. In class, students are given lectures on more difficult material and participate in group work that is also submitted for a grade. Statistical analyses were performed to compare exam data for the hybrid sections with exam data for the non-hybrid sections. We will share the results of our analyses, as well as the results of several surveys. (Received August 01, 2013)

1096-L5-438 **Gary A. Harris*** (gary.harris@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409, **Tara Stevens** (tara.stevens@ttu.edu), Texas Tech University, Department of Educational Psychology, Lubbock, TX 79409, and **Raegan Higgins** (raegan.higgins@ttu.edu), Texas Tech University, Department of Mathematics and Statistics, Lubbock, TX 79409. *The undergraduate mathematics preparation of middle school math teachers.*

The adoption by many states of the Common Core State Standards for Mathematics (CCSSM) and the publication of the Conference Board of the Mathematical Sciences document “The Mathematical Education of Teachers” (MET II) have raised questions about the mathematical knowledge of current teachers of mathematics , as well as, the mathematics preparation of future mathematics teachers. In this presentation we present results obtained from a five-year professional development project targeting middle school math teachers. These results involve effects on measures of teachers’ mathematics self-efficacy, mathematics knowledge for teaching, conceptual mathematics knowledge, and classroom practices. Then we discuss the ramifications for the undergraduate mathematics curriculum and delivery for future middle school math teachers. We conclude that undergraduate programs for future teachers should include a rigorous development of the fundamental mathematics concepts encountered in the middle grades. Moreover, we provide evidence that the sophisticated level of abstraction required for such a rigorous development is well within the capabilities of those students who enroll in upper division undergraduate mathematics courses which focus specifically on these concepts. (Received September 03, 2013)

1096-L5-488 **Karla Childs*** (kchilds@pittstate.edu), Pittsburg State University, 1701 S. Broadway, Math Department, Pittsburg, KS 66762, and **Jean Coltharp**. *The Relationship between Math Learning Communities and Student Retention.* Preliminary report.

Beginning in fall 2011 Pittsburg State University launched an innovative opportunity for freshman mathematics majors.

During their first semester, math majors are enrolled in a common Calculus I section and a special section of a freshman course designed to be a Math Learning Community.

We will discuss our experiences and initial research findings about the effects of Math Learning Communities on student performance. The question under investigation is: How do Math Learning Communities at Pittsburg State University affect GPA and Retention? (Received September 16, 2013)

1096-L5-538 **Susan S Gray*** (sgray@une.edu), Mathematical Sciences, 11 Hills Beach Road, Biddeford, ME 04005, **Barbara J Loud** (barbara.loud@regiscollege.edu), Mathematics Department, 295 Wellesley Street, Weston, MA 02493, and **Carole P Sokolowski** (carole.sokolowski@merrimack.edu), Mathematics Department, 315 Turnpike Street, No. Andover, MA 01845. *Does the Type of Variable Affect Undergraduates’ Interpretations of Algebraic Expressions?*

Previous research indicated that undergraduate mathematics students’ difficulties learning calculus could be related to weak understanding of the algebraic variable (White & Mitchelmore, 1996). Our previous findings indicated that students appeared to use variables incorrectly as labels when the variables were the first letters of the objects being quantified (Authors, 2005). Therefore, the goals of this study were to determine whether success rates on a paper-and-pencil survey in which 155 College Algebra students used and interpreted algebraic variables in expressions that represented quantitative relationships described in words differed according to the type of variable (first-letter vs. generic). Overall, success rates for these tasks were quite low and did not differ according to type of variable. Analysis of the types of responses indicated that many students were using both first-letter and generic variables as labels for the objects they were representing rather than as symbols that represented quantities. These findings suggest that many entering college mathematics students need more experience using and interpreting first-letter and generic variables in various contexts to support their development of a robust concept of the algebraic variable. (Received September 05, 2013)

1096-L5-835 **Kedar M Nepal*** (knepal@math.okstate.edu), 401 MSCS, Oklahoma State University, Stillwater, OK 74078. *An Investigation of Mathematics Graduate Teaching Assistants' Teaching Philosophies.* Preliminary report.

This is an investigation of the evolution of beginning mathematics graduate teaching assistants' teaching philosophies. Three teaching philosophy statements from each participant were collected at different stages of a semester long course 'Seminar and Practicum in the Teaching of Collegiate Mathematics' in the fall 2012 semester; this course was designed as a pre-service preparation program for graduate teaching assistants (TAs). The participant TAs did not teach or assume any other TA duties during the semester. The teaching philosophy statements were coded and then two follow up interviews were conducted with each participant after they began to teach and assume other TA duties. The first and second round interviews were conducted during the summer 2013 and the fall 2013 semesters, respectively. Principal elements found in their teaching philosophies and how their philosophies evolved over time during the pre-service and in-service phases will be discussed. The factors that influenced the teaching assistants' beliefs and their evolving teaching philosophies will also be discussed. (Received September 10, 2013)

1096-L5-1039 **H. Smith Risser*** (hrisser@mtech.edu). *An Examination of the Effect of Formative Feedback on Student Errors in a Calculus Course.*

The purpose of this study was to examine the impact of formative feedback on student errors. The study followed 50 students in a Calculus course. Each student turned in worked practice problems that they were either unable to solve or had solved incorrectly. The instructor for the course then provided written feedback on each individual student's work. In addition, the instructor gave whole group feedback for some common types of errors during class meetings. Student work from both formative and evaluative tasks was examined. Each error was assigned a code that indicated the type of error. These errors were broadly classified as attentional (e.g. dropping a constant from one step to the next), misunderstandings of prerequisite material (e.g. thinking functions can be distributed $\sin(2x) = \sin(2)\sin(x)$), or misunderstandings of the calculus content addressed in the course (e.g. not understanding how to apply a reduction formula). The study used Qualitative Comparative Analysis (QCA) to evaluate the effectiveness of the feedback in addressing student misunderstandings/misconceptions and preventing later errors. The results of the study indicate that for some groups of students the formative feedback did prevent future errors. (Received September 12, 2013)

1096-L5-1452 **Larissa B. Schroeder*** (schroeder@hartford.edu), Mathematics Department, University of Hartford, 200 Bloomfield Ave, West Hartford, CT 06117, and **Jean McGivney-Burelle** (burelle@hartford.edu) and **Fei Xue** (xue@hartford.edu). *Flip vs. Traditional: A preliminary comparison of student performance and attitudes in Calculus I.* Preliminary report.

Recently, increasing interest in "flipped" or inverted classes has resulted in mathematics faculty experimenting with this pedagogy. We will present the preliminary results from the second phase of a NSF funded project (DUE #1245059) at the University of Hartford comparing traditional lecture-based instruction and a "flipping" pedagogy. This quasi-experimental study, in which two faculty members each taught one section of traditional and flipped Calculus I, focuses on differences in student performance and understanding. In the flipped sections, initial exposure to the material was via department-produced videos; class time was dedicated to problem solving and discussion. In the traditional sections, instructors incorporated examples from the video into lecture, but provided minimal time for problem solving or discussion. Results include data from pre/post-tests of student understanding, student work on common mid-semester and final exams, student focus group interviews and student surveys. (Received September 15, 2013)

1096-L5-1863 **Cynthia Y. Young*** (cynthia.young@ucf.edu), Department of Mathematics, University of Central Florida, Orlando, FL 32816, and **Heidi A Eisenreich**. *The Impact of WHYU and the Khan Academy on Student Learning in Mathematics.* Preliminary report.

In the Fall 2012, a preliminary study was conducted at the University of Central Florida to ascertain the impact of animations (WHYU and Khan Academy) on student learning and affective measures in mathematics. Results of that study were presented at Joint Math 2012. In the Spring of 2013, the experimental design was altered and the impact of the Khan Academy was assessed in Intermediate Algebra courses and the impact of WHYU was assessed in Precalculus courses. Two Intermediate Algebra classes were taught with the same format with one exception- one class was shown one Khan Academy per week over 10 weeks. Two Precalculus courses were taught with the same format with one exception- one class was shown a 10 minute WHYU video on sequences and series. Three assessments were administered in both studies: one pre-test, one post-test immediately during

the week the content was presented and one post-test the last week of the semester. Results of these Spring 2013 studies will be presented. (Received September 16, 2013)

1096-L5-1938 **Jeremy Case*** (jrcase@taylor.edu). *The problem of transfer: Explicitly teaching critical thinking in a bridge course.* Preliminary report.

How effective is the explicit instruction of critical thinking skills in a bridge course to motivate students to learn mathematics and to transfer these thinking skills beyond mathematics? In order to overcome some students' aversion to proof, the presenter attempted to connect the process of proving mathematical statements with critical thinking in general. He received training to explicitly teach critical thinking and guidance to integrate mathematical thinking with critical thinking. As part of the training, a researcher observed and evaluated the presenter's teaching of critical thinking skills during every class period in an introduction to proofs course. This presentation will provide results from the daily observations, from the pretests and posttests measuring students' growth in individual critical thinking skills, and from student interviews. While the quantitative results are encouraging, the presenter will share personal insights regarding the effects of having an observer in the classroom and the challenges of motivation and transfer. (Received September 16, 2013)

1096-L5-2036 **Brad Bailey*** (bbailey@ung.edu), Dept. of Mathematics, 82 College Circle, Dahlonega, GA 30597. *A Modified-Moore Method in Precalculus: A Description of the Teaching Style and Student Outcomes.* Preliminary report.

In this talk we will describe a style of Modified-Moore Method being used at our institution in some of our Precalculus classes. This teaching style was developed as part of an on-going research project to study the impact of such inquiry-based practices on students' performance as well as the students' attitudes about mathematics and the learning of mathematics. The quantitative and qualitative methods used to measure and study this impact on students include both closed and open surveys, interviews and a standardized final exam. One of the instructors involved in the study will briefly describe how this method differs from Dr. Moore's original method and provide rationale for these departures. The instructor will provide details on the daily activities in the classroom and how students are motivated to participate. After describing the teaching style itself and our methodologies for studying its effects, we will share preliminary results from both the qualitative and quantitative components of the study. (This research is funded by a grant from the Education Advancement Foundation. PI, Thomas E. Cooper, Co-PI's Brad Bailey, Karen S. Briggs, and John E. Holliday.) (Received September 18, 2013)

1096-L5-2157 **Konstantina Christodoulopoulou*** (christod@uconn.edu), **Fabiana Cardetti** (fabiana.cardetti@uconn.edu) and **Steven Pon** (steven.pon@uconn.edu). *Analyzing Student-Generated Questions in Calculus.* Preliminary report.

An essential component of learning and scientific inquiry is asking questions. Analyzing the questions our students ask can contribute to a better understanding of students' learning difficulties and can inform changes in instruction. Although several studies have demonstrated the substantial educational potential of examining students' questions for science teaching and learning, significantly less has been done to study student questions in mathematics courses at the college level. The central research question of our study was: What do student-generated questions reveal about their understandings and misunderstandings from calculus lectures? The participants in this study were thirty-six students taking a business calculus course where lectures were delivered in short online videos. Data for this study consisted of 175 questions that the students generated after watching the videos. In this talk we will present the results of the qualitative analysis that reveal students' thoughts, struggles and successes, as well as provide insights for teaching improvements that support student learning. (Received September 17, 2013)

1096-L5-2248 **Gregory M. Boudreaux** (gboudrea@unca.edu), **Janine M. Haugh*** (jhaugh@unca.edu), **Ed Johnson** (ejohnson@unca.edu) and **Cathy Whitlock** (whitlock@unca.edu). *A Cost-Benefit Analysis of Online Homework Systems.* Preliminary report.

In recent years, a number of studies have been conducted to compare the potential pedagogical benefits and drawbacks of using online homework systems in introductory mathematics courses. These systems all allow students to submit assignments and receive instant feedback. They can vary tremendously, however, in cost, quality of user interface, and the types of additional student support services (e.g. worked out solutions to similar problems, e-book access, video tutorials) that are offered.

In the fall semester of 2013, four mathematics professors at UNC-Asheville set out to determine what their students value most in an online homework system. We obtained free access to three different systems (MyMathLab, Educosoft, and WebWork) which offer different levels of support and are normally offered at very different price points. After testing each system for a few weeks, students were given a survey to determine which features they valued most, and whether they would be willing to pay the actual retail price to have access to those features. Our findings will be presented. (Received September 17, 2013)

1096-L5-2259 **Sarah Bennett***, 1800 College Drive, Rice Lake, WI 54868. *Lesson Study: Collaboration, Improvement, and Reflection.*

Lesson study is a collaborative teaching improvement process that has origins in Japanese elementary education, where it is a widespread professional development practice. Four College Algebra instructors at UW-Barron County undertook a lesson study when teaching piecewise functions. Our goal was to investigate what effect a carefully designed lesson developed collaboratively would have on student learning. Students' mastery of the topic was assessed by a quiz and a Likert scale instrument was used to evaluate how the lesson was taught. Among other things, we learned that even if we think we have a polished lesson, students may not "get" it; some assessment of student learning is essential to find out what students comprehended. As a result, valuable changes were made, resulting in improved student learning. A second lesson study on inverse functions reflected similar findings. (Received September 17, 2013)

1096-L5-2471 **Ron Buckmire*** (ron@oxy.edu), Fowler 313, Mathematics Department, 1600 Campus Road, Los Angeles, CA 90041. *Investigating the effects of classroom voting and peer instruction on teaching and learning in an introductory differential equations course.* Preliminary report.

Classroom voting and peer instruction were implemented via the frequent use of electronic personal response devices (more commonly known as "clickers") in an upper-division Differential Equations course at a liberal arts college with small class sizes. The course was taught in four fall semesters (2008, 2009, 2010, 2013) by the same professor using nearly identical teaching materials and an identical summative assessment. For three of the four semesters, clickers were used to assess student learning, implement classroom voting and stimulate peer instruction. The impact of the use of clickers on differences in the teaching and learning of differential equations is being investigated, using various metrics and measures. Preliminary results suggest that overall student course grades as well as student performance on the common summative assessment instrument indicate improvement in student learning outcomes in the semesters when clickers were used. (Received September 17, 2013)

1096-L5-2476 **James S Rolf*** (jim.rolf@yale.edu), Department of Mathematics, Yale University, 10 Hillhouse Avenue, New Haven, CT 06511, and **Yu-Wen Hsu**, **Miki Havlickova**, **Susie Kimport** and **Jennifer Frederick**. *Using Video, Online Quizzes and Peer Instruction to Teach Integral Calculus.* Preliminary report.

We report on the initial implementation of an experiment to combine the use of short instructional videos, pre-class online quizzes, and peer instruction in Integral Calculus. Our goal was to push basic instruction outside of class via short videos and combine this with pre-class online quizzes to allow class time to focus on harder concepts and higher order thinking skills. We believed the availability of data from both video analytics and quiz responses would create an ideal Just-in-Time Teaching environment and enable the instructor to tailor class towards specific needs of the students. We also believed that using peer instruction would provide an effective mechanism to extend student knowledge in class.

We hypothesized that combining these three elements would positively impact both student learning and attitudes toward mathematics.

We will outline the experiment designed to assess each of these questions. In particular we will present data from pre/post tests and surveys, exam performance, and qualitative observations by neutral observers. Our analysis will attempt to discriminate whether the experimental condition is correlated with stronger performance on higher order questions, stronger engagement during class, and other perceptions that influence learning. (Received September 17, 2013)

Student Activities

1096-M1-76 **Brooke Buckley*** (buckleyb1@nku.edu) and **Bethany Noblitt** (noblittb@nku.edu). *Pi-Miler: An Irrational Race.*

This presentation will describe a run/walk organized by the Math and Stat Club at Northern Kentucky University. Instead of organizing a traditional 5K, which is 3.1 miles in length, the presenters will describe a 3.14 mile fun run. Initially, the fun run was organized as a way to celebrate Pi Day; however the event has also proven to be an excellent fundraiser for the club. The goals of this event are to hold an annual activity anticipated by students, faculty, and alumni which can also serve as the sole fundraiser for the organization. In the presentation, details for organizing such an event will be discussed, including planning the course, encouraging registration, working with campus security, and coordinating giveaways. The presenters will also indicate the amount of money which has been raised over the past two years for the Math & Stat Club. We hope to spark your interest to plan and implement your very own irrational race. (Received July 12, 2013)

1096-M1-301 **Jacci White*** (jacci.white@saintleo.edu) and **Monika Kiss** (monika.kiss@saintleo.edu). *Math Club Hosts Math Circle.* Preliminary report.

Having a math club host a math circle increases the confidence of the club member who is now the "expert" as well as making the math circle participant feel relaxed and comfortable. Math circles take a lot of time to coordinate but the jobs are easily divided among club members such as advertising, snacks, content, activities, parking, room reservations, and connecting with other groups on campus. A math circle can get many different parts of campus involved with the math club including faculty who send their children to participate, admissions who want to meet and possibly sponsor an event for the students, School of Education who might combine it with a teacher math circle, and the faculty within the mathematics department who might host the content on different weeks. This also gives math club members an opportunity to "try out" teaching in a fun environment and to think about their own mathematical conceptions in a different way. (Received August 27, 2013)

1096-M1-490 **Karla M Childs*** (kchilds@pittstate.edu), Pittsburg State University, 1701 S. Broadway, Math Department, Pittsburg, KS 64832, and **Jean Coltharp**. *Building Relationships with Student Activities in Math Learning Communities.* Preliminary report.

Beginning in fall 2011 Pittsburg State University launched an innovative opportunity for freshman mathematics majors.

During their first semester, math majors are enrolled in a common Calculus I section and a special section of a freshman course designed to be a Math Learning Community.

We will discuss Movie Nights, Pizza at Gorilla Village, Build-Your-Own-Sundae, Gorilla Expedition Scavenger Hunt, etc. (Received September 04, 2013)

1096-M1-665 **Emily H. Sprague*** (esprague@edinboro.edu), Mathematics and Computer Science, Edinboro University of Pennsylvania, Edinboro, PA 16444. *Reviving the Math Club at Edinboro University of Pennsylvania: 2007 – 2013.*

Seven years ago the Edinboro University Math Club was an occasional bowling party. Students laughed and called it the "We Hate Math" Club because its few members tended to use meeting times to complain about the difficulty of their classes.

By the Spring of 2013 the club produced four presenters, working under three faculty directors, all fired up to talk about their extra-curricular mathematical explorations at the Pi Mu Epsilon Undergraduate Research Conference at Youngstown State University. A fifth presenter came from a freshman seminar and we brought along a guest observer.

At the start of Fall 2013 we already have five club members hard at work on new projects and we expect a few more to emerge...

In this talk we will chronicle the sequence of distinct initiatives, ranging from drumming up participants for the Putnam Exam to establishing an annual Pi Day Party and preserving an annual Awards Ceremony through Math Club sponsorship, that we introduced to spark interest and raise the self-esteem of our students as well as to develop pride in the culture of mathematics and the sense of collegiality among faculty. (Received September 11, 2013)

1096-M1-1168 **Nicholas J Willis*** (nwillis@georgefox.edu), 411 N Meridian St., Box 6166, Newberg, OR 97132. *Building Community – The Good, the Bad and the Ugly.*

Building community among our math majors... What should we try?

Are you looking for new and innovative ways of building community among your math majors?

In this talk, I will discuss activities that work, activities that don't work, and things that I will never try again. (Received September 13, 2013)

1096-M1-1845 **Julie Barnes*** (jbarnes@email.wcu.edu), Department of Mathematics & Computer Science, Western Carolina University, Cullowhee, NC 28723. *Hosting mathematics treasure hunts.* Preliminary report.

In this activity, students work noncompetitively in teams to solve a variety of mathematics problems in order to collect clues that lead them to a treasure (once literally buried in dirt from the geosciences lab). The event has increased camaraderie between mathematics, mathematics education, and computer science students, but also increased visibility of our department because some students brought their friends to the event. In addition, students discovered areas of the building in which they typically do not venture. I have worked with colleagues from my department to create treasure hunts for our math club, but have also organized hunts with colleagues from my section for students that attend our section meetings. The version we run at the MAA section meeting is very similar, but larger in scale with roughly 80 - 100 students participating. Running a Mathematics Treasure Hunt does not have to cost much, and runs smoothly as long as you have enough volunteers to help. No matter how you run it, it is always a lot of fun. (Received September 16, 2013)

1096-M1-2030 **Deborah L Gochenaur*** (dlgochenaur@ship.edu), 1871 Old Main Drive, Shippensburg, PA 17257, and **Luis Melara** (lamelara@ship.edu), 1817 Old Main Drive, Shippensburg, PA 17257. *Mathematics – for life, for love, for a living.*

Realizing that student activities are interwoven into the overall life of the department gives us the opportunity to engage our students on multiple levels - socially, intellectually, and career "minded-ly". Kicking our semester off with a Meet the Freshmen social after the opening Majors Meeting in the fall helps us to set the stage for greater student involvement throughout the academic year, providing an opportunity for new students to begin forming social connections. Weekly colloquium help to build intellectual interest while serving as an opportunity for students to strengthen those social connections. In addition, our majors have opportunities to volunteer at events coordinated by faculty for students in K-12 as well as raising money for cancer research. And, just for fun, they can join the department's Fantasy Football League. While providing students with quality events outside of class is important for community, we will describe how we purposefully plan events as part of a multifaceted overall program. We will also discuss the logistical and planning challenges that are inevitable with multiple faculty members running different programs and events and how those challenges were overcome in an effort to best serve our students. (Received September 17, 2013)

1096-M1-2053 **Jennifer Bergner***, Dept. of Math/CS, 1101 Camden Ave., Salisbury, MD 21804. *The Radical Dash: A Mathematical Amazing Race.* Preliminary report.

Attending the section meetings of your local MAA chapter with your students is a great way to get them to see the world of mathematics outside of the classroom, but the sessions may seem overwhelming at first. To encourage students to attend and be involved in our meetings, the MD-DC-VA section has hosted a mathematical competition that is run concurrently with our spring meetings. We have had 60-85 of our undergraduates participate each spring. The students create teams of 2 to 5 and dash through a set of timed mathematical activities throughout the meetings. These activities have included a "Quiet Room" (think mathematics with limited symbols and no talking), a liquid arithmetic challenge, human knots, and life-sized mutually orthogonal Latin squares with picnic supplies. I will share some of the activities, how to design good activities, and the logistics of managing such an event. (Received September 17, 2013)

1096-M1-2264 **Janine E. Janoski*** (janinejanoski@kings.edu). *A Mathematical Scavenger Hunt.*

We will discuss a mathematical scavenger hunt run by the King's College Math Club during the Fall 2013 semester. The scavenger hunt will consist of math puzzles, which will lead to the location of the next clue. When the final clue is found, there will be a final puzzle to solve. In this talk we will discuss the problems we encounter, the implementation of the hunt, and the successes we see as a result of the activity.

Some hurdles we expect to see are the following. How do we design scavenger hunt clues that are both stimulating for the math majors while applicable for non-majors? What is the best way to choose teams so the hunt is fair? How do we design a hunt so the students can't find all of the clues without solving the math puzzles? How do we use this as an activity to increase membership in the math club?

We hope to resolve some of these issues by having the clues be more math and logic puzzles. There will be a check-in spot where students must check their answer before starting the next clue. We plan on advertising the scavenger hunt to the entire college community as a fun activity for anyone who enjoys mathematics and likes solving puzzles. With funding from our student government, we will give a prize to the winning team. (Received September 17, 2013)

1096-M1-2333 **Lidia Gonzalez*** (lgonzalez@york.cuny.edu), York College, CUNY, Attention: Dr. Lidia Gonzalez, 94-20 Guy R Brewer Blvd., Jamaica, NY 11451. *Activities for Undergraduate Students in Mathematics and Computer Science: Two Programs.*

This talk will focus on two programs that I organize to promote enthusiasm, confidence, and performance in mathematics. The first of these is the York Tensor Scholars Program, a mathematics circle aimed at challenging the under-representation of women in mathematics. The program is funded by the MAA and AAUW. Students attend a monthly talk given by a mathematician (most often a woman). The students then attend a social event with the speaker to get to know one another better and break down traditional beliefs of who mathematicians are and what they are like. I discuss the program and results from a research study exploring the effect of participation on students. The second program is an unfunded Math/Computer Science Club. Open to the entire college community, the club features weekly talks and activities related to mathematics, mathematics education and computer science. In addition to talks that form most of the club's events, there have been other events such as puzzle parties, a dominoes championship, movie screenings and related events. I discuss the program, specifically giving information about increasing participation, organizing meaningful events, and noting the effect of participation on students. (Received September 17, 2013)

1096-M1-2353 **Jeffrey Liebner*** (liebnerj@lafayette.edu), 232 Pardee Hall, Easton, PA 18042.
Breaking Codes for Mathematics Enjoyment (and Cash).

From the simplest Caesar cipher to the more complex RSA ciphers, mathematics and code writing have forever been intertwined. With the enticement of the challenge of decoding a hidden message and the exhilaration of succeeding, activities surrounding cryptanalysis are naturally appealing to people of all ages, especially those with an appreciation for the mathematics that is involved. In this spirit, the Lafayette College Math Club has hosted an annual Cryptography Competition which leads students through a race that is part code breaking and part scavenger hunt as teams compete for bragging rights and a cash prize. We will discuss the nature of the competition, the logistics involved, and the impact the competition has had on the mathematics club and the students of Lafayette College as a whole. (Received September 17, 2013)

1096-M1-2381 **Cathy W. Grilli** (cgrilli@cbu.edu), **George E. Gallarno*** (ggallarn@cbu.edu) and **Rebekah Herrman** (rherrma1@cbu.edu). *Lions and Tigers and Mathematicians.*

To promote community the Student Chapter of the MAA at Christian Brothers University engages students at each of its meetings through the use of group activities such as mathematical puzzles, Math Jeopardy, and using the Fibonacci sequence to construct the Golden Spiral. Signature activities include the annual Dress Like a Mathematician Halloween Party and Pumpkin Carving and our Mathematical Scavenger Hunt through the Memphis Zoo. When dressing like a mathematician, one can be interpretive rather than literal as long as the "Who Am I?" quiz is included. The Scavenger Hunt preparation involved several trips to the zoo where we hunted for mathematics that our teams would enjoy. Our talk will share our experiences with these activities so that they can be adapted for other groups. (Received September 17, 2013)

1096-M1-2514 **Stacey Muir*** (stacey.muir@scranton.edu), University of Scranton, Mathematics Department, Scranton, PA 18510. *The Evolution of an Integration Bee at the University of Scranton.*

The Math Department at the University of Scranton has hosted an annual Integration Bee since spring of 2008. Since that time, the bee has grown from a humble event held in a common area of a dorm with a small level of participation mostly of our own students to a regularly anticipated event involving students from both area high schools and local universities. We will discuss some unique aspects of our competition structure developed over the years that allows over 80 students to participate without using a pre-test and typically results in the completion of the competition in less than three hours. This structure is transportable to other universities and can be scaled up to a larger group of competitors. (Received September 17, 2013)

1096-M1-2567 **Ruth G Favro*** (favro@ltu.edu). *Math Club Favorites at Lawrence Technological University.*

Several of our most popular activities have been an Euler Symposium, with 10-minute student talks on any aspect of his work; building a Menger Sponge with donated business cards, as a group activity resurrected each year; and a Professors Used Books Sale, which has funded many of our activities. I will discuss these as well as the ups and downs of a Math Club whose members represent diverse majors. (Received September 17, 2013)

1096-M1-2689 **David E Molnar*** (molnar.math@gmail.com), Felician College, Department of Mathematics, 223 Montross Ave, Rutherford, NJ 07070. *A Non-Competitive ProblemFest.*

In 2013, the Felician College Math department held its first (hopefully annual) ProblemFest. This is a non-competitive event designed to extend interest in problem-solving beyond a core group of dedicated upperclassmen, and also to build community and have fun. I will provide details about the setup, outcomes, and future plans. (Received September 18, 2013)

Teaching with Technology: Impact, Evaluation, and Reflection

1096-M5-37 **Jason Cantarella*** (jason.cantarella@gmail.com), UGA Mathematics Department, Athens, GA 30602. *Taylor Turret Battle: An HTML5 video game teaching students to understand Taylor Approximation.*

Taylor Turret Battle is a small video game played on a browser under HTML5. Your student controls a small spaceship by turning and thrusting. A computer-controlled turret fires projectiles at the player. The goal is to survive as long as you can. The turret is aimed by an algorithm which uses Taylor series to predict the player's future position from their position, velocity, and acceleration at the time the turret fires.

One purpose of the game is to experiment with a familiar learning environment for students (gaming) which really depends on the computer. Students seem to get a very different understanding of the importance of making predictions with series approximations after interacting with the game, and they are forced to think deeply about Taylor series in order to figure out how to win.

The game is free, works in Safari, Firefox, and Chrome, and is available to your students (and you) at http://www.jasoncantarella.com/taylorturret

In this talk, we'll demonstrate the game and discuss the impact of the game on students and their responses to their experiences with the game. If time permits, we'll also talk about integrating activities with the game into the WebWork system, and the development process. (Received June 06, 2013)

1096-M5-138 **Eric Sullivan*** (esullivan@carroll.edu), Carroll College, Helena, MT. *Enhancing Student Writing with LaTeX and MATLAB in Multivariable Calculus.* Preliminary report.

In this presentation we will show how MATLAB can be used in conjunction with LaTeX to build students writing and visualization skills in multivariable calculus. In our multivariable calculus classes students are given an hour and a half per week of computer lab time where they complete investigative MATLAB activities. At the completion of the lab, MATLAB's powerful publish command allows students to create a full LaTeX document that embeds all of their code and figures. Students are then required to use LaTeX to give meaningful and thorough explanations of the mathematics in the form of a technical lab report. Several examples will be presented along with preliminary data of the effectiveness of this method. (Received August 07, 2013)

1096-M5-160 **John C Miller*** (xyalgebra@mindspring.com), 110 Riverside Dr. Apt. 14C, New York, NY 10024. *Beyond Short Answers: Improving Verbal Problem Software.* Preliminary report.

The Common Core Standards in Mathematics stress problem solving skills and applications, which in Basic Algebra implies verbal problems. Current verbal problem practice software too often accepts only a short final answer and too often responds to any incorrect short answer with a single stored solution, uninfluenced by the student's method.

Proper support requires accepting step-by-step solutions. Adequate response requires two types of algorithms. First, software must check each student step when entered for "correctness" in the appropriate sense, verbal, mathematical or both. Second, software must be able to suggest an appropriate next step, or type of step, at any intermediate point of any solution.

Such algorithms will be discussed and demonstrated, and implementation issues will be considered.

The presenter, who is retired and distributes his work at no cost to students and institutions, seeks discussions with both potential test sites and potential collaborators. (Received August 12, 2013)

1096-M5-170 **Brian J Winkel*** (brianwinkel@hvc.rr.com), 26 Broadway, Cornwall, NY 12518. *Technology Permeated Teaching of Differential Equations Course with Modeling at the Core.* Preliminary report.

From the beginning and throughout – that is the governing principle in our use of technology in teaching mathematics. Technology, in our case computer algebra systems and spreadsheets, are the go to instruments for student success, wherein simulations, solutions, structures, and success are within student reach. Technology empowers students to explore, to discover, to solve complex problems, and to report out their results in a professional manner. We illustrate this in a number of contexts. Further, we demonstrate an alternative approach to teaching differential equations through modeling and technology, in SIMIODE - Systemic Initiative for Modeling Investigations and Opportunities with Differential Equations in which collaborative learning over a HUB based web site we are developing (www.simiode.org) will support many technologies and much student interaction with other students and faculty through the use of technology. (Received August 12, 2013)

1096-M5-220 **Nell K. Rayburn*** (rayburnn@apsu.edu), Box 4626, Department of Mathematics and Statistics, Austin Peay State University, Clarksville, TN 37044, and **Samuel Jator** and **Bonnie Hodge**. *Maximizing the Effectiveness of an On-Line Homework System.*

This project compared three instructional strategies in College Algebra: 1) Lecture: Lecture three days per week, instructional software for homework; 2) Lab: Lecture two days per week, one day per week instruction in computer lab, instructional software for homework; 3) Group: Lecture two days per week, structured small group activities (without computer) one day per week, instructional software for homework.

The "Group" treatment yielded slightly higher success rates (in terms of course grades) and slightly higher scores on the common final exam. The Group treatment also resulted in higher persistence rates and better student attitudes regarding the on-line homework. (Received August 20, 2013)

1096-M5-489 **Hazel I. Coltharp*** (hcoltharp@pittstate.edu), Pittsburg State University, 1701 S. Broadway, Mathematics Department, Pittsburg, KS 66762, and **Danielle J. Frey**, KS. *Preparing Secondary Math Teachers in a Tablet World.* Preliminary report.

Pittsburg State University, a regional teacher preparation university in Southeast Kansas, prepares secondary mathematics teachers for Kansas and Missouri area secondary schools. To attempt to prepare students for what they'll be facing in area secondary schools, the Mathematics Department purchased tablets for each pre-service major and is piloting their use by incorporating tablet usage in methods courses, clinical experiences, and professional semesters. We will discuss the experiences of a recent graduate and the challenges faced by providing each pre-service mathematics education major with a tablet to use during their methods course and pre-professional semester. (Received September 04, 2013)

1096-M5-551 **Andrew Cooper*** (andrew.cooper@math.ncsu.edu), Box 8205, North Carolina State University, Raleigh, NC 27695. *Student Blogging in Major Courses.*

Student blogging has been used for a decade or more in college courses in fields ranging from anthropology to physics, but is not as widespread in mathematics. This talk will discuss blogging assignments I have used in undergraduate real analysis and transitions courses and assess some of their successes and pitfalls.

I will use sample student posts and comments to illustrate that a course blog can get students engaged with the course material in way that connects to the world around them, as well as enhance student understanding through low-stakes writing. Time permitting, I will also discuss some of the technical issues to emphasize that student blogging can be done without undue burden to the instructor. (Received September 05, 2013)

1096-M5-672 **Aaron Wangberg*** (awangberg@winona.edu), 322 Gildemeister Hall, Winona State University, Winona, MN 55987, and **Gulden Karakok**, **Nicole Engelke** and **Alees Seehausen**. *Transforming the Calculus Classroom with WeBWorK CLASS.*

Tablet technology, digital ink, and an online homework system like WeBWorK provides the ultimate classroom engagement system. By adding enhancements such as an integrated whiteboard, tree sorting, digital work maps, and classroom sharing to WeBWorK, WeBWorK CLASS (Collaborative Learning and Active Support System) was created. We will share how our implementation of WeBWorK CLASS in a first semester calculus course during the Spring and Fall 2013 semesters transformed the learning environment from lecture to active student learning. Besides providing students immediate feedback on practice problems outside of class, it provides the instructor access to authentic student work during class which may be used to generate discussion. Student generated solutions allow the instructor to facilitate learning by examining multiple solution paths, what constitutes appropriate mathematical notation/work, conjecturing, and making connections among concepts. Further, the system can be used to track student learning across the semester. (Received September 18, 2013)

1096-M5-945 **Geoff R Goehle*** (grgoehle@email.wcu.edu), 452 Stillwell, Western Carolina University, Cullowhee, NC 28723. *Math Achievements: Gamification and Online Homework.*

This talk describes how two popular gamification techniques, achievements and levels, were added to the online homework program WeBWorK. We will discuss the motivation behind these features and well as student response to these techinques. In particular we will consider how the system impacts student engagement and student learning. While some of the results of this talk are contained in the paper *Gamification and Web-based Homework* (PRIMUS, Vol. 23, Iss. 3, 2013), several new aspects will be discussed. These include "Achievement Items", a feature which is used to reward students for earning achievements, and a deeper analysis of the effectiveness of the achievement system. (Received September 11, 2013)

1096-M5-1321 **Lisa Townsley*** (townsley@math.uga.edu). *Going State-Wide with MOOC-like Precalculus in Coursera.*

The University System of Georgia has entered into an agreement with Coursera to offer courses for credit to USG students. Precalculus is the first course offered via this platform to undergraduate students in Georgia. Faculty from 5 USG campuses have designed this MOC (Massive Online Course, not "open") which will debut in January 2014. The speaker presents the scope of the course and the marriage of Coursera for content with WebAssign and a Cengage text for homework. The working philosophy is to develop a "virtual emporium model" for learning mathematics. As with all online learning environments, the student learner has a different role, as do the facilitators. Of particular interest to the design team is who will be drawn to such a course, and who will be successful. (Received September 14, 2013)

1096-M5-1584 **Robert Talbert*** (talbertr@gvsu.edu), Department of Mathematics, Grand Valley State University, 1 Campus Drive, Allendale, MI 49401. *Technology as a tool for self-regulated learning in an inverted calculus class.* Preliminary report.

For many, Calculus 1 is the first mathematics course taken in a college environment where personal responsibility, independent thinking, and higher-order reasoning play a significant role. Calculus 1 is also the first course in the Mathematics major and as such leaves a lasting impression on students regarding the nature of the discipline of Mathematics. If we want students to be successful not only in mastering calculus content but also in preparing for learning later in their majors and professions, Calculus 1 must engage students in *doing mathematics in the style of a professional*.

At Grand Valley State University, an effort is underway to re-invent the Calculus 1 course to place a deliberate emphasis on independence, self-regulated learning, and higher-order thinking by converting Calculus 1 to an inverted or "flipped" class design. In this talk, we will examine the role technology plays in this inverted calculus course and how its use by students is changing the ways they learn and do mathematics. In particular, we will focus on the use of screencasting to replace in-class lectures; classroom response systems to promote a conceptual approach to calculus topics; and dynamic geometry software and spreadsheets for modeling and coding. (Received September 16, 2013)

1096-M5-1619 **Mika K Seppala*** (mika.seppala@myweps.com). *WEPS Online Math Courses vs. Traditional Instruction.*

The WEPS Service (myweps.com) offers online courses. University of Helsinki offers five completely online courses in mathematics. The first open online course was offered in 2004, long before the invention of the word MOOC for such courses.

The University of Helsinki online math courses have been developed as an alternative to traditional courses. Initially they have been offered along with the traditional courses. Comparative studies have shown that the learning results of students of online courses have been better than those of traditional face-to-face instruction. In some cases, these online courses have then replaced the corresponding traditional courses.

In this talk I will discuss what makes the online instruction work.

References

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1096-M5-1678 **John Travis*** (travis@mc.edu), Box 4025, Mathematics, Mississippi College, Clinton, MS 39058. *WeBWorK Online Homework in an Introduction to Proofs course.* Preliminary report.

The use of automatically graded online homework has been successfully utilized for years across the lower-level mathematics curriculum. The upper-level courses have often been a more difficult environment for implementing these systems. In this talk, recent developments in the open source online homework system WeBWorK will be demonstrated as applied to a junior-level Introduction to Proofs course. (Received September 16, 2013)

1096-M5-2073 **Peter L Staab*** (pstaab@fitchburgstate.edu), Department of Mathmematics, 160 Pearl St., Fitchburg, MA 01420. *WeBWorK: Building the Next Generation to Make an Impact in the Classroom.* Preliminary report.

Webwork, the online homework system that over 300 institutions uses worldwide is modernizing. Those of us working on the project are looking to the next major version as an opportunity to create a homework system that the next generation of professors can adapt to their needs. We are looking to design an easier-to-use, more flexible and more-adaptive homework system that gives students the opportunity to practice mathematics problems (the original goal of WeBWorK), but also is useful in evaluation and assessment. This talk will discuss the direction of webwork including how a well-designed open-source framework can give its users the flexibility to adapt the software. We will address how current users are using WeBWorK to address issues like the impact of technology on teaching and learning to possible of using WeBWorK in new situations like adaptive learning environments. (Received September 17, 2013)

1096-M5-2283 **Barbara Kaskosz*** (bkaskosz@math.uri.edu) and **Doug Ensley** (deensley@ship.edu). *Mobile Delivery vs. Paper and Pencil: A Comparison of Student Learning.* Preliminary report.

Mobile Math Apps is an NSF-funded project designed to put precalculus-level learning objects on smartphones and to assess the way students interact with this material and how these interactions affect student learning. The assessment plan includes controlled experiments to test retention of material delivered via mobile device as opposed to paper-and-pencil. In the implementation of this project, we collect a rich set of usage data for a group of precalculus students, and we correlate that data with student performance on benchmark assessments within the course. This presentation will include a brief demonstration of the mobile app design, and a focused discussion of the early results of our study. (Received September 17, 2013)

1096-M5-2354 **Michael B. Scott*** (mscott@csumb.edu), Mathematics and Statistics Department, California State University, Monterey Bay, 100 Campus Center, Seaside, CA 93955. *Using Online Technology to Improve Student Learning in Mathematics Courses.* Preliminary report.

Cal State Monterey Bay uses a web-based homework system to supplement Pre-Calculus, Calculus and other mathematics courses. The infrastructure of the online homework has been expanded into a full course management system for coordinating every aspect of the course and serving as a platform for delivering supplemental resources to students. These resources include, but are not limited to, exam study guides, course notes and video lectures. Expansion of the system makes possible the collection of rich data streams about individual students. In addition to course grade data such as exam, homework and quiz scores, items such as college entrance exam scores, GPA, course resources students accessed are also included in the data. The presenter will discuss the measurement, collection, analysis and reporting of these data for the purposes of understanding and optimizing students' learning experiences using online technology. (Received September 17, 2013)

1096-M5-2501 **Joe Latulippe*** (jlatulip@norwich.edu), 158 Harmon Drive, Mathematics Department, Norwich University, Northfield, VT 05663. *A complete technological transformation: From chalk to clickers and PowerPoint.* Preliminary report.

Implementing new teaching strategies can be daunting, but after many years of teaching university calculus using traditional lectures, it was time for a change. In this talk we will explore my transition from reliance on a chalkboard to an all-encompassing technological classroom environment. In my efforts to increase student engagement in the classroom, a review of teaching research led me to using clickers and in-class voting in calculus. I will share lessons learned, pitfalls, and insights about incorporating PowerPoint slides and clicker questions into calculus lectures. In addition to reflections on my own teaching transformations, a preliminary report on the impact of clickers on student performance and engagement will be presented. (Received September 17, 2013)

1096-M5-2591 **Jennifer Kosiak*** (jkosiak@uwlax.edu), 1004 Cowley Hall, 1725 State Street, Mathematics Department, La Crosse, WI 54601, **Robert Hoar** (rhoar@uwla.xedu), 227 Graff Main Hall, University of Wisconsin - La Crosse, 1725 State Street, La Crosse, WI, **Robert Allen** (rallen@uwlax.edu), 1015 Cowley Hall, 1725 State Street, Mathematics Department, University of Wisconsin - La Crosse, La Crosse, 54601, and **Jim Sobota** (jsobota@uwlax.edu), 116 Cowley Hall, 1725 State Street, Mathematics Department, La Crosse, WI 54601. *College Readiness Math MOOC: A Fast Track Approach.*

At the post-secondary level, there has been an increasing number of students enrolled in remedial mathematics courses. This session will describe the development, implementation, and evaluation of the FastTrack summer math program designed for incoming college freshman who placed into a remedial mathematics class. Students spent six weeks online working through digital materials, WebWorK homework, and online office hours integrated within a College Readiness Math MOOC (Massive Open Online Course). This online program was followed by a one week face-to-face workshop prior to the start of the semester. In this talk, we will discuss the success of this program including the impact on student learning through the analysis of both quantitative and qualitative measures. We will also discuss the use of these technologies and the transferability of the Math MOOC to other university settings. (Received September 17, 2013)

1096-M5-2634 **Paul E. Seeburger*** (pseeburger@monroecc.edu), Monroe Community College, 1000 E. Henrietta Rd., Rochester, NY 14623. *To What Extent Does Visualization Improve Conceptual Understanding in Multivariable Calculus?*

An online exploration applet called CalcPlot3D allows students and instructors to create and freely rotate graphs of functions of two variables, contour plots, vectors, space curves, regions of integration, vector fields, parametric surfaces, and implicit surfaces. 3D glasses can be used for a real 3D perspective! Come get a pair and try it out! This applet has been used by over 1000 students from all over the country to complete various concept exploration activities that include a pre-test, an exploration for which students use the applet to explore a concept visually and answer provided questions, and a post-test. These explorations are intended to get students to "play" with the concepts visually. Topics for these concept explorations were the Dot Product, the Cross Product, Velocity and Acceleration Vectors (in the context of motion along a plane or space curve), and Lagrange Multiplier Optimization. The data presented will include analysis of these pre- and post-test results, student comments on their own learning from questions at the end of these explorations, and data from various other sources. 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 17, 2013)

1096-M5-2668 **Douglas B Meade*** (meade@math.sc.edu), Department of Mathematics, University of South Carolina, Columbia, SC 29208, and **Philip B Yasskin** (yasskin@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77843-3368. *Maplets for Calculus: Impact on Learning and Other Lessons Learned.*

The first release of Maplets for Calculus (M4C) in 2005 contained 37 customized graphical user interfaces for topics in precalculus and single-variable calculus. The collection of maplets has now increased to more than 200 and the range of topics has expanded to include complex numbers, multivariate calculus and differential equations.

Over the years, the M4C have improved in many ways that increase their usability in a wide range of teaching and learning environments. For example, to be used for graded homework it is necessary to disable the displaying of hints and solutions.

Evaluation data shows that student attitudes towards the use of technology in their calculus course depends on exactly how they are used in the course. The latest results from these surveys will be discussed.

This presentation summarizes some of the general lessons learned and demonstrate how these lessons have impacted the development of specific maplets. We will also discuss the next steps in the M4C project, including the challenges to creating versions of the M4C that can be used for graded homework from mobile devices. (Received September 17, 2013)

1096-M5-2669 **Michael D Miner*** (jcmhs77@aol.com), 65 Edenbrook Drive, Hampton, VA 23670. *The Impact of Technology in Teaching College Mathematics to Nontraditional Students in Nontraditional Learning Environments.* Preliminary report.

As text book publishers and authors are now providing more robust learning and support tools to their products, the question becomes "are students learning and retaining more?". This study seeks to understand the impact of learning and retention of college mathematics concepts as taught to nontraditional students in nontraditional learning environments using publishers' tools. This study will examine enabled learning and assessment tools and the effect of these tools on learning and retention of college mathematics concepts. The findings will be based on data collected from nontraditional students in nontraditional learning environments and seeks to support the claim that the categorized students learning and retention of college mathematics concepts are more pronounced than that provided by traditional learning and assessments techniques. (Received September 17, 2013)

1096-M5-2699 **Lee Windsperger*** (lwindsperger@winona.edu), Gildemeister 322, Department of Mathematics & Statistics, Winona State University, Winona, MN 55987, and **Aaron Wangberg**. *Mathematical Investigations Using Interactive Graphing Tools in Precalculus.* Preliminary report.

Every topic in a typical precalculus course could easily provide opportunities for students to generate patterns, propose conjectures, and discuss conditions regarding the unknown underlying mathematical phenomena. The challenge, of course, is in the presentation! Interactive graphing tools provide one way to make precalculus concepts accessible to students before theorems and algebraic rules are revealed during lecture. In this talk, we will share activities and interactive graphing tools developed using the free, open-source Javascript library JSXGraph from the University of Bayreuth. These interactive graphing tools work on all web platforms and provide a quick means for the investigation of graphical phenomena. Furthermore, the tools developed using JSXGraph provide opportunties for students to apply precalculus concepts to data anaylsis. We will also highlight data collected from three sections of precalculus on how the interactive graphing activities are (a) impacting student learning, (b) shifting student expectations and the classroom learning environment, and (c) broadening student concepts of mathematical thinking. (Received September 18, 2013)

1096-M5-2749 **Michael Rene Kent*** (mkent@bmcc.cuny.edu), Borough of Manhattan Community College, Mathematics Department N599A, 199 Chambers Street, New York, NY 10007. *Teaching and Learning with Technology in a Community College: How far it has come; How far could it go; What makes it effective; How it might evolve?* Preliminary report.

This paper intends to gleam some working principles on effective use of technology in education. It recognizes deep advances in technology from desktop computers to hand held devices. It looks at the history, development and evolution of digital devices applied in education. Furthermore, it intends to lead towards improving learning of applied concepts in mathematics. It hopes to help teachers lead students to create mathematical memories by way of discovery, visualization or just practice. It interlaces practice and theory of technologies that are used as learning tools and considers researchers both from here and abroad.

It will refer to research, studies and situational observations performed by the author as well as by others. (Received September 18, 2013)

Topics and Techniques for Teaching Real Analysis

1096-N1-97 **Radoslav Dimitric*** (dimitricr@member.ams.org), New York, NY. *Notions of function and continuity in college mathematics.* Preliminary report.

These are two most fundamental notions relevant not only to mathematics, but to the sciences and beyond. The rendering of these notions both in textbooks and in daily teaching practice leave much to be desired. I discuss some reasons that I believe lead to these problems and propose ways to teach functions and continuity not only correctly but most efficiently and with greatest utility. (Received July 26, 2013)

1096-N1-535 **Kathleen M. Shannon*** (kmshannon@salisbury.edu), 1101 Camden Ave, Department of Mathematics and Computer Sci., Salisbury University, Salisbury, MD 21801. *It's Not the Moore Method But..: A Student Driven Textbook supported Approach to Teaching Real Analysis.* Preliminary report.

Most universities cannot offer multiple real analysis courses for different audiences. Also students come to the course with prerequisites taken at different times, or different institutions and with differing levels of mastery. And few students have mastered the technique of reading mathematical texts, which our graduates should have some ability to do. So the challenge is to have an environment where diverse students can flourish and attain the necessary skills for their differing personal goals. Clearly some kind of student-centered approach is needed. Proponents of the Moore Method would argue that it is perfectly suited to this situation. However, some of us find that in what is often a one-semester experience, too many students do not achieve mathematical maturity quickly enough to benefit fully from such a course. I will describe a student-driven method which allows movement through the standard course material with differing depths but the same pace. I have used this methodology in classes for over 25 years and have seen considerable student success. It has also worked successfully with four very different textbooks. We use a combination of boardwork followed by class discussion, on-demand brief lecture, written homework and exams, and a course portfolio. (Received September 05, 2013)

1096-N1-547 **Erik Talvila*** (erik.talvila@ufv.ca). *Applications of the Alexiewicz norm.*

An important concept that is frequently introduced in a real analysis course is that of a norm. The p-norms for series and integrals are often used. These are not always applicable to a conditionally convergent series or integral. In this case, the most useful norm is that of Alexiewicz. It has a straightforward and intuitive definition. We will go over its main properties for sequences and series. (Received September 05, 2013)

1096-N1-643 **Peter A Loeb*** (ploeb@illinois.edu). *Local Maximum Functions in Real Analysis.*

Differentiation and absolute continuity are difficult topics for students in a beginning real analysis graduate course or an advanced undergraduate program. We present a simplified approach that has cut almost in half the time previously spent by the author in covering these topics. The time saved is used for a deeper discussion of Hilbert spaces and Fourier analysis. Our simplified approach is based on joint work with Juergen Bliedtner of Frankfurt University. That approach, using a local maximal function, was originally developed to deal with limit theorems in various settings. The advantage gained is that measure derivatives and other limit results can be established just by proving the results for sets where the relevant input vanishes. Our approach also employs a very short proof from first principles of the general Lusin theorem (joint with Erik Talvila), and an optimal covering theorem for the real-line by Jesus Aldaz, extending work of T. Rado. (Received September 08, 2013)

1096-N1-777 **William C. Bauldry*** (bauldrywc@appstate.edu), Boone, NC 28607. *Reorganizing a First Course in Real Analysis.* Preliminary report.

We present an alternative introductory real analysis course that is suitable for undergraduates in all mathematics major tracks. The proposed course was developed from a graduate level survey of real analysis course for teachers in a mathematics education masters program. Benefits of this course for undergraduates who only take a single semester of real analysis are discussed along with directions a second semester may take. (Received September 10, 2013)

1096-N1-898 **Jeffrey Clark*** (clarkj@elon.edu). *Using Counterexamples of Calculus to Teach Real Analysis.*

Some of the most important results in the first semester of Real Analysis are theorems of the first semester of calculus. Many students have an intuition for these theorems but learned them without a focus on rigor. This talk will discuss using counterexamples to these theorems (when casually phrased) to help develop the rigor that is a process goal for the class. (Received September 11, 2013)

1096-N1-1042 **Robert W. Vallin*** (robert.vallin@sru.edu), Department of Mathematics, 200 Vincent Science Center, Slippery Rock, PA 16057. *Gently Introducing IBL in Advanced Calculus.*

Many potential users of Inquiry-Based Learning are unsure as they desire to not completely convert the class over. Instead they desire a way to make only part of the class IBL. A couple of years ago, I got the chance to run such a hybrid class when I was given the second semester of our Advanced Calculus sequence while not having taught the first. The students' first semester was the usual lecture/homework model, not one that I wanted to continue. My desire was to have them work on atypical problems and develop their ability to create counterexamples and communicate mathematics. However, I did not want the transition to my style to be too abrupt. So I developed our *Presentation Fridays*. Monday and Wednesday the professor lectures as usual and we followed the prescribed text. On Friday the students themselves did the presenting, solving exercises designed to expand their collection of examples and to extend the topics beyond just what was in the book. In this talk I will introduce the circumstances of the class, show a wide selection of the problems/examples from class, and share some students comments on Presentation Fridays. (Received September 12, 2013)

1096-N1-1143 **Judit Kardos*** (kardosj@tcnj.edu). *Constructing continuous functions.*

If the intersection of a decreasing sequence of compact sets in R^2 defines a function graph over the closed interval $[0, 1]$ then the resulting function will be continuous on $[0, 1]$. In this talk, we use compact sets formed by closed rectangles and connecting line segments to define a plethora of continuous functions with remarkable properties. Since these functions are defined by geometric constructions, their intuition defying properties are visible and verifiable using geometric arguments.

The resulting graphs not only help students crystallize the notion of continuity but also provide a safe playing field for their mathematical imagination. (Received September 13, 2013)

1096-N1-1476 **Robert Kantrowitz*** (rkantrow@hamilton.edu), 198 College Hill Rd., Clinton, NY 13323, and **Michael M. Neumann** (neumann@math.msstate.edu). *A close look at the geometric series test.* Preliminary report.

The geometric series test is one of the first results about convergence of infinite series that students encounter in calculus and real analysis. We spotlight this test to see what properties of the real numbers are required for its proof and to consider possibilities for its exportation to other settings such as abstract ordered fields. (Received September 15, 2013)

1096-N1-1485 **Paul Martin Musial*** (pmusial@csu.edu), Chicago State University, Department of Mathematics, Comp. Sci and Econ, 9501 South King Drive, Chciago, IL 60628. *Spice up your Real Analysis Class with In-Class Presentations.*

Preparing an in-class presentations gives a student a taste of doing mathematics research. The student must, in consultation with the instructor, choose a topic, complete a literature search and put together the actual presentation, complete with equations, figures and references. In addition, in class presentations give the instructor a great opportunity to assess students' learning outcomes. In this talk we will discuss ways of having undergraduate students in a real analysis course make effective in-class presentations. (Received September 15, 2013)

1096-N1-1677 **William T. Mahavier*** (ted.mahavier@lamar.edu). *Two sets of Moore-Method Analysis notes and two websites that support them.*

Real Analysis may be one of the most challenging courses to teach at the undergraduate level. Students often come to such a class with minimal skill at writing and creating mathematics. For just this reason, a well-designed class may take a student with budding talent and create a true mathematician. On the other hand, a poorly thought out course may deaden the student's interest in this beautiful pure, yet applicable area of mathematics. Having taught analysis for more than eighteen years, we discuss our Moore Method approach to the course and the websites we developed to support those who might wish to use them. (Received September 17, 2013)

1096-N1-1992 **J. Marshall Ash*** (mash@math.depaul.edu), Department of Mathematics, DePaul University, Chicago, IL 60614. *Teaching positive series and generalized derivatives.*

A topic that is always covered in first year calculus and often also covered in elementary real analysis is the determination of whether an infinite series of positive real numbers converges. I will display a simple diagram that helps my students organize their thoughts on this question. Another topic that is often touched on while a real analysis class is studying differentiation is generalized differentiation. Usually a very small number of examples involving generalized derivatives appear as exercises that are interesting, but disconnected from the general flow of the subject and from each other. I will present some of these and tie them together. (Received September 17, 2013)

1096-N1-2052 **Kimberly J Presser*** (kjpres@ship.edu), Shippensburg University, Department of Mathematics, Shippensburg, PA 17257. *Using Daily Quizzes to Build Proof Skills in a Real Analysis Course.* Preliminary report.

In my introductory coursework, I frequently use daily quizzes as a way of encouraging students to stay on top of the material being presented in class. These quizzes are quick checks of their understanding on the material presented in the previous class or assigned for the evening reading.

In the 2013 spring semester, I employed this technique in our upper level Real Analysis course. Since writing a whole proof is not really reflective of the quick nature of these assignments, the quizzes focused on proof concepts. For example, students were asked to construct examples or counterexamples for definitions from the reading. Other days, the quiz focused on the structure of standard proofs, such as epsilon-delta arguments.

The purpose of this talk is to discuss the techniques employed, student performance on these daily quizzes, student feedback on the technique and the impact in performance on the departmental assessment of proof-writing for Real Analysis. (Received September 17, 2013)

1096-N1-2186 **Marion Weedermann*** (mweederm@dom.edu), Dominican University, 7900 W Division Street, River Forest, IL 60305. *Hybrid Course Modules in an Introductory Real Analysis Course.*

In an introductory course in real analysis two selected topics, the limit of a sequence and the Cantor middle third set, were introduced through a series of short videos rather than traditional lectures. The videos were recorded using a whiteboard app for iPad (Educreations), posted online and viewed prior to class. We discuss findings on the design of such hybrid modules, methods to ensure compliance, student understanding and performance as well as feedback received from the students. (Received September 17, 2013)

1096-N1-2324 **Cesar E. Silva*** (csilva@williams.edu). *One Proof is Not Enough.* Preliminary report.

Often a deeper understanding of fundamental ideas comes from knowing more than one proof of the important theorems. We will discuss examples of how to use this technique in a real analysis course. In particular we will discuss the manifold proofs of Cantor's theorem and the new ideas they involve. Part of this is based on joint survey paper with my former student, Christina Knapp. (Received September 17, 2013)

1096-N1-2347 **James Peterson*** (petersonje@alma.edu), Department of Mathematics, Alma College, Alma, MI 48801. *A classic counterexample examined in greater detail.*

Examples of functions whose Maclaurin series fail to represent the function on open intervals of any size are often relegated to the exercises in calculus and analysis texts. Closer examination of such functions can not only lead to better understanding by students of the (rare?) failure of power series techniques, but a closer knowledge of the proof of Taylor's Inequality and the Mean Value Theorem. (Received September 17, 2013)

1096-N1-2540 **Mark McKinzie***, Dept. of Mathematical and Computing Sciences, St. John Fisher College, 3690 East Ave, Rochester, NY 14618. *Using Student Screencasts to Present Content in a Real Analysis Class.* Preliminary report.

This Fall, I used screencasting for student presentations in my Real Analysis II class. In this talk, I'll give a brief introduction to techniques for creating screencasts (using a free on-line tool at `screencast-o-matic.com`), describe the role these presentations played in my class (students presenting proofs of theorems from the text), and discuss the pedagogical benefits and pitfalls we experienced. (Received September 17, 2013)

1096-N1-2563 **Rebekah B. Johnson Yates*** (`rebekah.yates@houghton.edu`). *Helping Students Overcome Discouragement in Real Analysis.*

In Real Analysis, students' intuition repeatedly proves incorrect. As they begin to rebuild their intuition correctly, the process of creating precise definitions often causes discouragement. I will describe a few techniques I have used to help my students overcome their discouragement, including homework conferences and specific assignments that allow students to reflect on what they know and explore their understanding from different angles. (Received September 17, 2013)

Trends in Undergraduate Mathematical Biology

1096-N5-426 **Timothy D Comar*** (`tcomar@ben.edu`), Department of Mathematics, Benedictine University, 5700 Collge RD, Lisle, IL 60532. *Mentoring Undergraduate Research in Mathematical Biology.*

We discuss the preparation process of undergraduate students to participate in undergraduate research activities. Most of the students with whom I have worked began their preparation process in my two semester biocalculus course sequence. During this course sequence, students learn how to read journal articles, work with computer software, and complete an expository project on a mathematical model from a journal article. Students then continue research activities through the Benedictine University College of Science Summer Research Program, which operates like an REU, through independent research work during the school year, and through a research oriented topics course. I will also discuss the structure and functioning of the research groups during the school year, in which more advanced research students begin to help mentor novice student researchers. We conclude with a summary of recent results obtained with my research students in the dynamics pest management and epidemic models using impulsive differential equations and the dynamics of Boolean models of gene regulatory networks. (Received September 03, 2013)

1096-N5-859 **Carrie Diaz Eaton*** (`ceaton@unity.edu`). *Can Furry Animals and Albedo Replace Epsilons and Deltas in Calculus?*

Calculus classes targeted towards undergraduate students in Biological Sciences are designed with highly conceptual learning objectives important in modeling. Faculty in the biological sciences are look for learning outcomes from Calculus that may be different from the traditional Calculus sequence, and often with increased credit constraints. Content shifts in curriculum have replaced some advanced symbolic manipulation techniques with difference or differential equations and technological tools for modeling. Does this trade-off hinder students' understanding of traditional Calculus concepts?

We find that students enrolled in Biocalculus I perform as well as their counterparts in Calculus I conceptual knowledge gains, even as well as their active learning counterparts when corrected for contact hours, and have an increased appreciation for the role of mathematics in their everyday lives and careers as well as the intrinsic value of mathematics. (Received September 10, 2013)

1096-N5-1262 **Melissa A Stoner*** (`mastoner@salisbury.edu`). *Impacts of Introducing Projects to a Calculus for Biology and Medicine Course.* Preliminary report.

Based on reports released in 2010, mathematics is quickly becoming important for science majors as their career fields change and adapt to handle the world's newest problems. At Salisbury University we have created a course, MATH 198, which is designed to be a rigorous differential calculus course with a biological focus. In order to combat some of the issues that arose in this course, we have implemented a group project as part of the course as a precursor to a more project-based teaching approach. This talk focuses on the consequences both positive and negative to this adjustment and future plans for a more integrated calculus and biology course. (Received September 14, 2013)

1096-N5-1530 **Marilyn Brandt** (mbrandt@uvi.edu), 2 John Brewers Bay, University of the Virgin Islands, St. Thomas, VI 00802, and **Robert Stolz*** (rstolz@uvi.edu), 2 John Brewers Bay, University of the Virgin Islands, St. Thomas, VI 00802. *Locally-relevant biological projects as a foundation for teaching an upper level undergraduate math course.*

In the fall of 2012, the University of the Virgin Islands offered a project-based course on Numerical Analysis taught by a Professor of Mathematics and a Research Assistant Professor of Marine Biology. A significant component of students' grades included three group projects where they applied techniques programming skills that they had learned in class to problems that were territorially relevant and based on real data. These projects included: 1) Developing a system for lionfish control in Virgin Islands marine reserves, 2) Application of the classic Kermack-McKendrick SIR model of disease to dengue fever in the Virgin Islands, and 3) Modeling the dynamics of coral bleaching over a 9 year period using data from the US Virgin Islands Territorial Coral Reef Monitoring Program. Methods taught and then applied in the projects included the Bisection Method, Newton's method, and Runge-Kutta methods, among others. At the end of the course, students were asked to anonymously evaluate the role of the projects in the course. The majority of students (9 of 10) agreed that the biologically-based projects helped them to learn the numerical analysis techniques. (Received September 16, 2013)

1096-N5-1777 **Shantia Yarahmadian*** (syarahmadian@math.msstate.edu), **Hadi Khani** and **Eda Asili**. *A Mathematical Modeling for Alzheimer's disease and its Treatment Based on the Metal Hypothesis.*

A mathematical model for studying Alzheimer's disease focusing on the formation of Amyloid beta fibrils aggregation in the in the presence of metal ions with a treatment based on chelating agent is presented. (Received September 16, 2013)

1096-N5-1945 **Rebecca-Anne Dibbs**, Greeley, CO 80634, and **Brian Christopher*** (brian.christopher@unco.edu). *Formative assessment and classroom community in calculus for the life sciences.* Preliminary report.

Most of the attrition from STEM majors occurs between the first two semesters of calculus, and prospective life science majors are one of the groups with the highest attrition rate. One of the largest factors for students that persist in STEM major beyond the first semester of calculus was a sense of community and a perceived connection with their instructor. Since building a sense of community is one of the stated purposes of formative assessment, we investigated to what extent formative assessments could help build a sense of community in a calculus for life science majors course. This talk will discuss two cases of formative assessment used in two sections of this course. When implemented as intended, the formative assessments completed weekly by the students made a positive contribution to students' sense of classroom community and their perceived connection with their instructor. (Received September 16, 2013)

1096-N5-1950 **Dan Hrozencik*** (dhro@att.net), Dept. of Mathematics - HWH 332, 9501 S. King Dr., Chicago, IL 60423, and **Tim Comar**. *Undergraduate Research in Gene Regulatory Networks.*

Across several academic years, the authors have sustained research projects with multiple students in the area of gene regulation. The students began working on projects comparing the dynamics of discrete and continuous models of gene regulatory networks and have branched into the study of synchronous dynamics and their relation to network structure. The authors will present information regarding the content of the projects, including recent results on the dynamics of networks with two feedback loops. In addition , the prerequisite knowledge of the students conducting the research, as well as information about the resources needed to maintain such an ongoing research program will be discussed. (Received September 16, 2013)

1096-N5-2187 **M Drew LaMar*** (mdlama@wm.edu), Department of Biology, The College Of William and Mary, 2137 Integrated Science Center, Williamsburg, VA 23187, and **Carrie Diaz Eaton**, **DorothyBelle Poli**, **Anil Shende**, **Robert Sheehy**, **Eungchun Cho** and **Eric Friedman**. *QUBES Hub: A vision of online collaboration in teaching and learning in quantitative biology.*

As quantitative tools are recognized as more important to biologists, and biological applications of more interest to mathematicians, an interdisciplinary approach to education in these areas is crucial. Curricular materials for quantitative biology education are being developed at a number of levels; by individuals, via department or college initiatives, and through various professional societies. This dispersed approach has resulted in multiple, non-communicating, repository sites, many of which remain opaque to the quantitative biology community and makes the sharing of information and ideas difficult. To address these difficulties in information sharing, we are creating a compact between several organizations devoted to this common mission of Quantitative Undergraduate Biology Education and Synthesis (QUBES). Our goal is to bring these organizations together to sponsor a single, dynamic, community-sourced hub of educational materials and social-network of users. We will present a review of some of the existing and planned functionality of QUBES, and solicit feedback and requested features from those in attendance. (Received September 17, 2013)

1096-N5-2323 **Rhyzl Ayang-ang Guimbatan*** (rguimbatan@dcccd.edu), 1912 Foxwood Dr, Mesquite, TX 75181. *Biological Hacking by Stem Cells Derived from Gompertz Function Modeling.* Preliminary report.

Scientific breakthrough showed successful regeneration of cells in an organism's damaged tissue through the aid of stem cells. This "biological hack" allows a part of the body re-program itself with the use of these stem cells that behave somewhat like a tumor. This presentation focuses on mathematical modeling of stem cell kinetics derived from the Gompertz function, a sigmoid curve modeling of tumor growth. Using Mathematica as the main platform for curve-fitting, the model is then externally rendered into a three-dimensional model. (Received September 17, 2013)

1096-N5-2433 **Sean M Laverty*** (slaverty@uco.edu) and **Brittany Bannish**. *Hands-on classroom demonstrations for a life sciences calculus course.* Preliminary report.

We present examples from a small catalog of successful in-class demonstrations for a sophomore-level bio-calculus course. Our goal is to generate excitement and intuition for mathematical concepts and methods. We focus on labs that take a minimal investment of student (and faculty) time, both in and out of the classroom. We have had success finding borrowed or donated supplies from experimental Departments in our College. Demonstrations often take 15-20 minutes of class time at the start of each chapter. We begin with a simple population dynamics experiment using yeast, used to emphasize and review variables, parameters, measurement, calculations, graphing. We return to this exercise to discuss discrete-time dynamical systems, using the data to build a model. We study the Newton's Law of Cooling problem, measuring and discussing average and instantaneous rates of change to motivate the limit and the derivative. Later we revisit this data to introduce elementary differential equations and their solutions. Lastly, we introduce integration by using measured velocities to predict the position of running and walking students during a 'race'. In this talk, we discuss objectives, mechanics, and pitfalls of these examples. (Received September 17, 2013)

1096-N5-2675 **Eric J Kostelich*** (kostelich@asu.edu), School of Mathematical & Statistical Sciences, Arizona State University, Tempe, AZ 85287-1804, and **Yang Kuang** (kuang@asu.edu), School of Mathematical & Statistical Sciences, Arizona State University, Tempe, AZ 85287-1804. *An Undergraduate course on the Mathematics of Cancer.*

This talk describes a course, Mathematics and Cancer, that is targeted toward third-year undergraduates and students who have recently transferred from two-year institutions to four-year undergraduate programs. Besides the mathematical topics that we cover, I will discuss the larger mentoring role that this course plays in the undergraduate program, including exposure to some of the primary scientific literature, choosing a semester research project, and giving oral and written reports. (Received September 17, 2013)

1096-N5-2742 **Rebecca Dibbs*** (rebecca.dibbs@unco.edu), Greeley, CO 80639, and **Anne-Marie Hoskinson** (amhoskinson@gmail.com). *Breathing life into mathematics for biologists: teaching quantitative practices to undergraduate biology students.*

In light of numerous recent calls for reforming teaching and learning in undergraduate biology, instructors of biology and mathematics are seeking ways to increase both quantitative literacy of students and relevancy of problems to their professional development. We propose that mathematics instructors can enrich biology students' numeracy skills by focusing on three practices: engaging multiple representations of data (graphs, tables, equations, narratives), solving authentic problems, and building models. We illustrate the implementation of disciplinary practice-based instruction with case studies of two courses: calculus for the life sciences, taken at the beginning of the biology major, and mathematical modeling in biology, taken at the end of the major. By focusing on disciplinary practices rather than content alone, we equip students to master the fundamental concepts of both mathematics and biology. (Received September 18, 2013)

USE Math: Undergraduate Sustainability Experiences in the Introductory Mathematics Classroom

1096-P1-147 **James A. Walsh*** (jawalsh@oberlin.edu). *Climate Models and Differential Equations.*

We report on recent efforts aimed at bringing climate modeling into the sophomore ODE course. Energy balance models focus on major climate components, including incoming solar radiation, planetary albedo, and outgoing longwave radiation. First order autonomous ODEs arise naturally when the dependent variable is global average surface temperature. The role played by atmospheric greenhouse gases in warming our planet is easily incorporated into the models. Bifurcations of equilibrium points occur as physically relevant parameters are varied. Examples of corresponding student activities will be presented. We also provide a brief report on student reaction to this material. (Received August 09, 2013)

1096-P1-1137 **Victor J. Donnay*** (vdonnay@brynmawr.edu), Department of Mathematics, Bryn Mawr College, Bryn Mawr, PA 19010. *Using Solar Panels to Teach Integration.* Preliminary report.

Bryn Mawr College has a small solar array, the data from which is displayed in real time on the college's sustainability webpage. The system records the power generated by the solar panels (in watts) at 5 minute intervals and then makes a graph of power vs. time. We use this data to give a real world example of integration. Starting from the basic relation that energy = power x time, we find that the total energy produced by the solar panels is the area under the power curve. Since the power curve is given by discrete data points rather than an analytic function, determining the area involves Riemann sums or other geometric methods rather than taking an anti-derivative. This calculus lesson can be adapted for use in a variety of courses including pre-calculus, quantitative reasoning, and mathematical modeling. The example responds to the student lament: "Why did the professor confuse us with all that stuff about Riemann sums when we could have just taken the anti-derivative". (Received September 13, 2013)

1096-P1-1423 **Lori Carmack*** (lacarmack@salisbury.edu). *Should I Unplug?* Preliminary report.

The 2013 MAA PREP Workshop: USE Math on Your Campus at Shippensburg University (organizers: Corrine Taylor, Ben Galluzzo, James Hamblin) inspired attendees to incorporate sustainability topics into their teaching. Workshop organizers presented various ideas and encouraged attendees to design and publish related teaching materials. This paper presents a student assignment, titled "Should I Unplug?" that was developed as a result of attending the workshop. In the assignment, students use a wattage meter to measure "plug loads" of various electric devices and small appliances commonly found in students' living spaces. They compute the monetary costs of leaving these products plugged in longer than necessary and estimate how much money they could save in a year by eliminating these unnecessary plug loads. In addition, they estimate how much money a university could save in a year if students were to "unplug" in dormitories, and think about the broader implications of this issue. (Received September 15, 2013)

1096-P1-1642 **Amanda I Beecher*** (abeecher@ramapo.edu). *USE Math in First-Year Seminar.* Preliminary report.

I am developing a First-Year Seminar to introduce students to sustainability initiatives on campus from a quantitative perspective. I use Ramapo College's existing sustainability policies and practices to contextualize the course and keep it relevant to the students. The course highlights the importance of reliable data in assessing the effectiveness of these initiatives, as well as students' role in their success. This course incorporates many modules developed and presented at the USE Math MAA PREP workshop in Shippensburg University this summer. (Received September 16, 2013)

1096-P1-1868 **Elizabeth Biernat*** (ebiernat@brynmawr.edu), Department of Mathematics, Bryn Mawr College, Bryn Mawr, PA 19010, **Victor Donnay** (vdonnay@brynmawr.edu), Department of Mathematics, Bryn Mawr College, Bryn Mawr, PA 19010, and **Hannah Weinstein** (hannahjweinstein@gmail.com), Penn Graduate School of Education, University of Pennsylvania, 3700 Walnut St, Philadelphia, PA 19104-6216. *Is it "Worth It" to Change Your Light Bulbs?*

Is it "worth it" to change the light bulbs in your home or school from incandescent to compact flourescent or LED? This intriguing, open-ended prompt is the start of a problem-based unit on mathematical modeling in which students grapple with the question of how to define "worth it" and how to translate their definition into mathematics. To reach their conclusions, students must learn about power (watts and kW) and energy (kWh), and then consider how factors such as cost of electricity, product lifetime, payback time, and even carbon footprints may influence their decision to change the light bulbs. This low-threshold, high-ceiling problem can be approached at a variety of levels and provides opportunities for students to represent mathematics in numerical, graphical and analytical form. The unit concludes with students presenting their findings, focusing on the mathematical analysis that informed their conclusion, and making recommendations for change on campus. (Received September 16, 2013)

1096-P1-1878 **Bill Bauldry*** (bauldrywc@appstate.edu), Appalachian State University, **Victor Donnay** (vdonnay@brynmawr.edu), Bryn Mawr College, and **Lynn Reed** (lreed@nsf.gov), Office of Polar Programs, National Science Foundation. *Arctic Sea Ice Activities in Class.*

We present the results of using a classroom activity based on arctic sea ice extent data from 1979 to the present at the secondary and lower division undergraduate level. (Received September 16, 2013)

1096-P1-2518 **Kathleen R Fowler*** (kfowler@clarkson.edu), 8 Clarkson Ave, Box 5815, Department of Mathematics, Potsdam, NY 13699. *Multi-level Undergraduate Research in Sustainable Water Use for Agriculture Management.*

We describe how a real-world application in sustainability was used for undergraduate research with students in varying stages of their education. The focus on this work is understanding the trade-offs in practices for berry farming in the Pajaro Valley of California. The groundwater supply is being overdrawn due in part to agricultural pumping. We are trying to understand how changes in planting schedules could help lessen the impact, which is currently resulting in seawater intrusion along the coast. To this end, we use mathematical modeling, optimization, and simulation to gain insight and seek solutions. Undergraduate students, ranging from pre-freshmen to seniors, have made significant progress on this work while simultaneously gaining an appreciation for mathematics and its role in planning for the availability of future natural resources. (Received September 17, 2013)

1096-P1-2600 **Charles Buehrle*** (cebuehrl@hacc.edu), Mathematics Department, Harrisburg Area Community College, One HACC Drive, Harrisburg, PA 17110. *Commuting: A Sustainability Activity in an Intermediate Algebra Course.*

Getting students excited about mathematics in a developmental course is always difficult. One way to peak their interest is to relate examples to their everyday life and to their place in the world. This single class period activity has the students look up data, use unit conversions, and compare rates of quantities to draw conclusions. The students are asked to investigate the cost, carbon output, and time of their commute to and from school and a more ecologically conscious alternative. We will be presenting the reactions and results of using this project in an intermediate algebra classroom. (Received September 17, 2013)

1096-P1-2712 **Lily S Khadjavi*** (lkhadjavi@lmu.edu), Dept. of Mathematics, 1 LMU Drive, Suite 2700, Los Angeles, CA 90045. *To Mauna Loa and back again: bringing analysis of climate change data to life.*

Most students enter the classroom already believing that climate change is happening. The scope and pace of this change, however, is infrequently a topic of concrete discussion. Data from NASA and NOAA are easily accessed, but how can students be more actively engaged in analyzing it? We will discuss strategies to use climate change data in a variety of courses, including ways for students' analyses to take on a more personal meaning to them, both in the choice of data sets and writing assignments. (Received September 18, 2013)

Using Online Resources to Augment the Traditional Classroom

1096-P5-171 **Brian J Winkel*** (brianwinkel@hvc.rr.com), 26 Broadway, Cornwall, NY 12518. *Creating and Using Online Community Resources for Teaching Differential Equations with Modeling and Technology.* Preliminary report.

We are involved with building an on-line presence www.simiode.org in support of an effort to offer an alternative approach to teaching differential equations through modeling and technology, in SIMIODE - Systemic Initiative for Modeling Investigations and Opportunities with Differential Equations. While the major thrust of SIMIODE is to fully engage students in modeling scenarios which lead to differential equations study and use, coupled with ever present technology use, with the on-line material fully supporting the learning community of students and teachers, thus no longer requiring expensive texts, we believe such modeling scenarios can enrich any class in differential equations. We will show why. (Received August 12, 2013)

1096-P5-194 **Paul R Bouthellier*** (pbouthe@pitt.edu), 504 East Main Street, Titusville, PA 16354. *Allowing Students and Educators to Create Their Own Web Based Mathematical and Statistical Simulations.*

In this talk we shall show a web site which will allow students and educators to create their own web based mathematical and statistical simulations. A web site which contains several complete statistical simulators in the form of interactive lottery tickets has been created using HTML and JavaScript/JQuery. These simulators can be used in statistics classes to illustrate concepts such as probability distributions, means, variances, and what-if analysis. The code (which is easily viewable in any browser) of each simulator is commented in detail so as to show how easy it is to create such simulations. Another page in the site provides step-by-step instructors and illustrations to allow people (even with no programming experience) to create their own simulators. The already created examples serve as complete examples. Allowing students and educators to create their own mathematical and statistical programs will allow them to explore mathematical and statistical concepts in any course they wish. (Received August 15, 2013)

1096-P5-380 **James P. Howard, II*** (jphoward@faculty.umuc.edu). *Augmenting the Classroom with Web-Based Interactive Demonstrations.*

This presentation will look at using the Wolfram Demonstrations and Wolfram—Alpha Widgets to augment the classroom. These tools, which provide an interactive environment for mathematical experimentation, are freely available and provide a rich set of capabilities. Those capabilities include rapid deployment, real-time updates, and symbolic computation. Further, there are thousands of freely available interactive examples ready to deploy in undergraudate instruction. Finally, examples of combining these tools with other freely-available are presented. Focus is given to applying these tools in the introductory college mathematics courses along with discussion of the purely online mathematics education environment. (Received September 06, 2013)

1096-P5-388 **Revathi Narasimhan*** (rnarasim@kean.edu), Dept. of Mathematics, Kean University, 1000 Morris Avenue, Union, NJ 07083. *History Alive! Online Resources in a History of Mathematics Course.*

Using a variety of online documents and multimedia resources, we discuss how the history of mathematics can be made more meaningful and contextual. Integrating the wide array of material from outside the classroom can be daunting in a course that already has substantial content to cover. However, by realigning the course through mathematical themes and contexts, we were able to integrate the abundance of online material ranging from art history to original documents to video broadcasts about the history of mathematics. Through the use of online resources, we will see how a history of mathematics course can achieve a certain depth that would not be possible in a traditional lecture and textbook classroom. (Received September 01, 2013)

1096-P5-570 **Vesna Kilibarda*** (vkilibar@iun.edu). *Solving Applications in Business, Life Sciences, and Transportation using Excel and Java Applets.*

The goal of any mathematics class, be it online, hybrid, flipped, or traditional classroom, is to empower students to analyze and solve real-world problems and social issues using the power and rigor of mathematical and statistical models. A challenge is how to interest our students in mathematical problem solving, especially in service courses. I found that two types of written assignments, *paired* and *group projects*, enable my students to respond to these challenges. Both assignments integrate real world applications, writing, reading, technology, collaborative work, prompt feedback, and opportunities for revision.

In *paired assignments* students simulated the Birthday Problem with Excel or used Java applets to predict long term trends in transportation. Students also commented on a peer post by a due date. In *group assignments* students were solving problems, reviewing their group members' posts, revising them as necessary, and submitting one final group project containing a revised group work.

I first developed these assignments in my online class and adopted them for the face-to face class in the following semester. I received feedback from both my peers and students and will share specific assignments and feedback in my paper. (Received September 06, 2013)

1096-P5-579 **Mike May*** (maymk@slu.edu). *Working in a Laptop Classroom: Wolfram Alpha, WeBWorK Reading Quizzes, Google Help, and Modeling Data from the Web.*

Following the recommendations of the chapter on Business and Finance in the 2004 Crafty report on the Voices of Partner Disciplines, the author has created an online book for teaching calculus to business students that assumes students will use Excel on a laptop as their ordinary computational tool. This results in a rethinking of the classroom when a laptop connected to the internet is a regular part of the class. This talk will focus on other features of the classroom that have been modified by that assumption. A guiding principle is that the students can tools that they expect will be available on a generic business desktop in 5 years. A partial list of web augmentations of the class includes: Wolfram Alpha is available for graphing that is too cumbersome for Excel and for CAS to do problems that can be set up in the course, but require techniques beyond the course; Reading quizzes are established and do at the beginning of class to promote richer discussion; Google web searches are generally superior to application help; Student assignments include finding and creating models for problems. The talk will discuss issues that arise wight he change in class setting. (Received September 06, 2013)

1096-P5-652 **Amanda M Harsy Ramsay*** (aharsy@iupui.edu). *How online teaching has made me a better face to face instructor.*

This talk will discuss how my experience teaching completely online mathematics has improved my face to face teaching. Teaching completely online is challenging and requires some extra creative thought to be successful. As I strove to become a better online instructor, I discovered I was learning methods that would also improve my in-class teaching. This talk will specifically discuss several online tools I have successfully implemented in my face to face classes. Some examples include using online discussion boards, Echo Smartpens, and Adobe Connect. (Received September 08, 2013)

1096-P5-943 **Geoff R Goehle*** (grgoehle@email.wcu.edu), Stillwell 452, Western Carolina University, Cullowhee, NC 28723. *Essay Answers: Using Free Response Questions in WeBWorK.*

Online homework systems like WeBWorK are an important tool for the modern classroom because they provide students with instantaneous feedback. However, free response questions, which are difficult for computers to grade, are largely absent from the WeBWorK problem library. This talk presents a recent addition to WeBWorK which enables instructors to ask free response questions. Student answers to these questions are then manually graded by the instructor. Key features of the system are the ability for instructors to provide feedback to students via comments and the ability to integrate free response questions with traditional computer graded questions. (Received September 11, 2013)

1096-P5-1960 **Michael E Gage*** (gage@math.rochester.edu), Department of Mathematics, University of Rochester, Rochester, NY 14627. *Using WeBWorK, Geogebra and other online resources in a Linear Programming course.* Preliminary report.

In this talk I will discuss my experiences using new features of WeBWorK such as essayQuestions, combined with embedded Geogebra applets and other online materials, to create a set of online homework questions that help solidify students' algebraic and geometric understandings of linear optimization and the simplex method.

The main objective will be to indicate the range of possibilities for online questions that can be achieved by using these tools in combination. (Received September 16, 2013)

1096-P5-1996 **Philip B. Yasskin*** (yasskin@math.tamu.edu), Department of Mathematics, Texas A&M University, 3368 TAMU, College Station, TX 77845-3368, **Douglas B. Meade** (meade@math.sc.edu), Department of Mathematics, University of South Carolina, Columbia, SC 29208, and **Matthew J. Barry** (komputerwiz.matt@gmail.com), Department of Mathematics, Texas A&M University, 3368 TAMU, College Station, TX 77845-3368. *Maplets for Calculus: Expanding offerings and opportunities in Precalculus, Calculus and Differential Equations.*

The Maplets for Calculus v.1.3 is an ICTCM award-winning, and NSF supported, collection of 129 applets that tutor students in precalculus and calculus. The new release, v.1.4, has over 200 applets, including 13 new applets on precalculus (including 5 on complex numbers), 11 on limits, 9 on derivatives, 3 on integrals, 1 on series, 8 on geometry and vectors, 2 on partial derivatives, and 4 on differential equations. Some of these will be presented in the talk. We will emphasize how they have proved useful in the classroom as well as for out of class study. Most of these were initially designed by students in honors calculus classes at Texas A&M University. We will a;so demonstrate our initial attempts at converting the Maplets into the Java-independent MYMathApps Lessons which will work in any browser including those on mobile devices. (Received September 17, 2013)

1096-P5-2334 **Paul E. Seeburger*** (pseeburger@monroecc.edu), Monroe Community College, 1000 E. Henrietta Rd., Rochester, NY 14623. *Creating Effective Online Homework Problems in Calculus (Using WeBWorK).* Preliminary report.

WeBWorK provides many ready-made problems that can be used immediately in our courses, including a wonderful selection of graphical and conceptual problems for which students must understand the concepts to obtain correct answers. There are also many problems that only ask students to enter a final numerical answer (e.g., limits, definite integrals, line integrals). Unfortunately, many students are tempted to use their calculators (or

Wolfram Alpha) to directly calculate these results. Even the best students sometimes take this approach, 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 calculus. (Received September 17, 2013)

1096-P5-2506 **Elizabeth B. Uptegrove*** (uptegrovee@felician.edu), Department of Mathematics, Felician College, 223 Montross Avenue, Rutherford, NJ 07070. *Using Videos to Enhance Preservice Teachers' Understanding of Mathematical Justification and Proof.*

This report illustrates how videos, from a publicly available online database showing elementary and high school students working on problems in combinatorics, were used in a junior-level math class for students planning to be middle school or high school math teachers (preservice teachers). The preservice teachers worked on combinatorics problems themselves and then analyzed videos of elementary and high school students working on the same problems. The videos show that young students are capable of doing serious mathematical work. Because preservice teachers have limited opportunity to observe how students construct solutions to problems, access to online videos provided them with an opportunity to study the representations and heuristics employed by the students. It also provided them with insight into how younger students think about and do mathematics. Further, these videos also gave the preservice teachers an opportunity to study young students' informal justification processes, showing them how informal justification can be related to formal proof. By the end of the semester, the preservice teachers had demonstrated improvement in two areas: 1) their ability to identify the reasoning of younger students and 2) their ability to generate accurate mathematical proofs. (Received September 17, 2013)

1096-P5-2511 **Michael B. Scott*** (mscott@csumb.edu), Mathematics and Statistics Department, California State University, Monterey Bay, 100 Campus Center, Seaside, CA 93955. *Using Online Technology in the Mathematics Classroom to Improve Student Learning.* Preliminary report.

Cal State Monterey Bay uses a web-based homework system to supplement pre-calculus, calculus and other mathematics courses. The infrastructure of the homework system has been expanded to include web-based group quizzes in the classroom. These web-based quizzes were piloted in a pre-calculus course during the Fall 2013 semester. The web-based quizzes are used as a formative assessment tool to elicit student understanding and/or misconceptions of mathematical ideas and techniques, and provide feedback on student work that moves learning forward in real-time. These quizzes can be accessed using classroom computers, laptops or other mobile devices such as a smartphones or tablets. The presenter will report on the overall effectiveness of the web-based quiz concept as it relates to student learning. How this web-based resource was incorporated into the classroom and can be adapted to almost any online homework system by a wide-range of institutions will also be discussed. (Received September 17, 2013)

1096-P5-2582 **Karl-Dieter Crisman*** (karl.crisman@gordon.edu). *Thou Shalt Compute, in One Click: Using (Embedded) Sage Cells Online.*

Courses like Linear Algebra, Number Theory, and Calculus have been transformed by easy access to technology; numerical methods and huge exact computations alike are at our students' fingertips. But how can we use these resources outside of lab-based courses?

In this talk, we demonstrate several ways to use the free, open-source Sage cell technology to encourage students to deal with computation in as painless a manner as possible. One click is all it takes, whether embedding factorization of huge numbers in course notes or asking for responses to an interactive version of pre-class reading. Everything is in the browser - no downloads or plugins needed.

As long as you have an incentive or requirement to go online for each class (e.g., putting homework on BB/Moodle), just one more click brings them right to the computation. And since the Sage cells can be made fully editable, don't be surprised if you find - as I did - that they start doing their *own* computation before long! (Received September 17, 2013)

1096-P5-2587 **J. Lyn Miller*** (lyn.miller@sru.edu). *An Online Smorgasbord for Future Elementary Teachers.*

Math for elementary teacher courses are rich with opportunities for students to interact with relevant, timely web resources that supplement a traditional face-to-face setting. Just as we aim for these students to master a variety of content and pedagogical approaches, so too should we model variety by our choice of web content styles. This talk will share my favorite FREE web collections or solo sites that involve reading, viewing (reliable) video lessons, or using virtual manipulatives in order to engage or demonstrate varied learning styles, sometimes in class and sometimes outside it. A bias toward written sites aims additionally to strengthen my students' own reading skills and reiterate the importance of their training in literacy education, a key certification requirement at all levels in our state. (Received September 17, 2013)

1096-P5-2601 **Jennifer Kosiak** (jkosiak@uwlax.edu), 120 Cowley Hall; 1725 State Street, Mathematics Department, University of Wisconsin-La Crosse, La Crosse, 54601, **Bob Hoar*** (rhoar@uwlax.edu), 227 Graff Main Hall, University of Wisconsin-La Crosse, La Crosse, WI 54602, **Robert Allen** (rallen@uwlax.edu), 1015 Cowley Hall: 1725 State Street, Mathematics Department, University of Wisconsin-La Crosse, La Crosse, WI 54601, and **Jim Sobota** (jsobota@uwlax.edu), 116 Cowley Hall, 1725 State Street, Mathematics Department, University of Wisconsin-La Crosse, La Crosse, 54601. *A College Readiness Math MOOC: Online Resources for Remedial Mathematics.*

This talk will explore the development and implementation of a College Readiness Math MOOC (Massive Open Online Course). This course utilized several easy-to-create web-based resources to support student learning in mathematics. These resources included digital learning objects, self-contained mathematical tasks, which include video podcasts and other supporting material. The learning objects were clustered and sequenced into modules to form an online course. We will also discuss the integration of WebWorK as a homework platform and the use of online collaborative rooms that allowed for students to interact with the instructor and other students. We will also present evaluation data on the success of this program. The Math MOOC and its course resources are readily available on any platform and can be used as supplemental material for remedial or developmental mathematics classes. (Received September 17, 2013)

1096-P5-2643 **Jason Grout*** (jason.grout@drake.edu). *Sage mathematics software in the classroom.*

Sage (http://sagemath.org) is a free open-source mathematics software system with a powerful web interface. The Sage Cell server (https://sagecell.sagemath.org) provides an easy way to embed live computations directly into any web page with just a few lines of copied javascript and HTML. These computations can include 2D and 3D plots, sliders, buttons, and other interactive controls, and can use Sage, R, Octave, Python, and a variety of other programs. You can also use permalinks and QR codes to link to live computations from paper resources. The Sage Cloud (https://cloud.sagemath.com) provides a more comprehensive environment for doing computations, writing TeX documents, and collaborating with others. We will introduce how to use these resources in your teaching and materials. (Received September 17, 2013)

Wavelets in Undergraduate Education

1096-Q1-245 **Patrick J Van Fleet*** (pjvanfleet@stthomas.edu), 2115 Summit Avenue OSS 201, Department of Mathematics, University of St. Thomas, St. Paul, MN 55105. *The Morphological Wavelet Transformation.* Preliminary report.

The discrete wavelet transformation (DWT) is a popular tool in image processing. The DWT decomposes an image into an approximation of the original as well as details at a prescribed number of levels. While the transformation provides local information about the low- and high-pass nature of the data, it does not provide other desired information such as a maximum value and its position in a local region.

In this talk, we will describe the morphological wavelet transformation (MWT) due to De and Chanda. This nonlinear, invertible variant of the discrete Haar wavelet transformation (HWT) not only decomposes the image into an approximation and details, but also provides information regarding maximum values and their positions. De and Chanda have used the MWT to develop an efficient algorithm for performing image fusion.

We will conclude the talk by detailing a couple of student projects that utilize the MWT. (Received August 22, 2013)

1096-Q1-261 **Edward F Aboufadel*** (aboufade@gvsu.edu), Dept of Mathematics, A-2-178 MAK, Grand Valley State University, Allendale, MI 49401. *3D Printing and Wavelets.* 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 describe how wavelets and other mathematical tools can be applied to create and print interesting objects. (Received August 24, 2013)

1096-Q1-454 **Yevgeniy V Galperin*** (egalperin@po-box.esu.edu), East Stroudsburg University, Department of Mathematics, 200 Prospect St, East Stroudsburg, PA 18301. *Incorporating Wavelets into a course "Mathematics in Modern Technology".*

We discuss our experience teaching wavelets within the framework of a course titled "Mathematics in Modern Technology". The course is intended for students with very limited background in mathematics and has been successfully taught at East Stroudsburg University of Pennsylvania since 2008. (Received September 03, 2013)

1096-Q1-1087 **Robert D Dolan*** (dolan030@connect.wcsu.edu), 170 Sprucedale Drive, Waterbury, CT 06706. *M-Band Wavelet-Based Audio Watermarking Algorithm.*

As digital music has become increasingly popular, there is a great need to further develop a method that could be used to enhance copyright protection in the music industry. This paper addresses this problem by providing a way to protect against unauthorized copying of digital music by inserting a watermark in the audio file through the use of discrete wavelet transforms and other statistical means. The proposed watermark algorithm will achieve two goals: (1) The embedded watermark will not affect the quality of the audio in any way; (2) The watermark should be able to prevent common attacks that could remove or destroy the watermark, such as re-sampling, compression, amplitude scaling, and time scaling. (Received September 12, 2013)

1096-Q1-1166 **Malena Ines Espanol*** (mespanol@uakron.edu), Department of Mathematics, The University of Akron, Akron, OH 44325-4002. *Wavelet-Based Multilevel Methods for Eigenvalue Problems.*

The discrete wavelet transform provides restriction and prolongation operators for multigrid-type iterations. In this talk, we will outline a wavelet-based multilevel method to solve discrete eigenvalue problems. We will show the results of a summer undergraduate research project where this method was used to solve the discrete time-independent Schrödinger equation. (Received September 13, 2013)

1096-Q1-1438 **Bruce Atwood*** (atwoodb@beloit.edu) and **Lingzhi Meng**. *Forecasting with Wavelets Projects.* Preliminary report.

Improving time-series forecasts using wavelets is an attractive idea. By taking "weighted averages" and "weighted differences" the new time series obtained from the wavelet transformation are expected to have a simpler structure than the original data. Thus extrapolation of the transformed data followed by the inverse wavelet transformation should improve on results obtained simply by extrapolating the original time series.

Student projects can be developed around the two major problems that emerge from this approach. First, what is the best way to extrapolate? The new time series obtained after the wavelet transformation should be easier to extrapolate, but it still must be extrapolated. Second, wavelet transformations (except for the Haar) generate their own boundary effects. These must be treated carefully as their extrapolation can seriously affect the results. Both of these challenges have been explored, and results will be presented. (Received September 15, 2013)

1096-Q1-1551 **Ashley E. Orr*** (aorr@student.ysu.edu), Youngstown, OH. *Making Waves in the Business Cycle: Applying Wavelet Transforms to Economics.*

Comparable to a wave, the US economy seems to ebb and flow with economic fluctuations such as supply and demand shocks, political pressures, and labor productivity changes. Business cycles and their cyclic characteristics, represented by non-stationary time series, have been predominately analyzed by Fourier analysis. However, Fourier analysis does not consider both the time and frequency components of the time series simultaneously, making wavelet transforms a reasonable alternative to revealing the frequency fluctuations and the time at which they occur in the business cycle. This talk will look at how the business cycle is dated and how wavelet transforms in Matlab can be used. (Received September 16, 2013)

1096-Q1-1871 **Katherine Weber***, klw20@geneseo.edu, and **Chance Rodriguez**, **Tiffany Reyes**, **Erlan Wheeler** and **Amber Emmell**. *Haarmony: Chord Recognition Using Wavelets and Other Methods.*

Our research examined whether a computer, using Matlab, can effectively distinguish between different musical chords. We employed the signal processing techniques of wavelets, Fourier analysis, and raw data analysis to determine which method best enabled the computer to correctly recognize guitar chords. We will discuss basic overviews of the theory behind each of these methods, explain how we collected our data and implemented our algorithm, and report on the accuracy of each method. In addition, we will provide evidence for why we think each method worked as it did. (Received September 16, 2013)

1096-Q1-1895 **Beth Kate Matys*** (matye101@gettysburg.edu), **Ayush Singhal**, **Sarah Coulson**, **Karina Pena** and **Joel Venzke**. *Signature Authentication Using Wavelets and Fourier Analysis.* Preliminary report.

We explore three different methods to authenticate a signature given a data bank of genuine signatures. After quantifying the signatures, we use raw data, wavelet, and Fourier analysis to authenticate them. We compare the reliability of these three methods and conjecture the reasons behind the strengths and weaknesses of each. (Received September 16, 2013)

1096-Q1-2336 **John C. Merkel*** (jmerkel@oglethorpe.edu). *Whale Shark Identification via Discrete Wavelets.*

This talk reports on a project that utilizes discrete wavelets to identify individual whale sharks via digital images. The images were obtained from the website whaleshark.org. Whaleshark.org maintains a database of whale shark images and attempts to track their position through images and data submitted by the public. (Received September 17, 2013)

1096-Q1-2633 **Brenda T. Gonzalez**, **Jasmine Puente*** (jmpuente@miners.utep.edu) and **Helmut Knaust**. *Image Fusion of Satellite Images.*

We present the results of a MAA-NREUP summer research project at the University of Texas at El Paso. Image fusion combines a high resolution gray-scale satellite image with a lower resolution multispectral satellite image to produce a multispectral image of higher spatial resolution. Techniques presented include color transfer methods as well as methods using discrete wavelet transformations (DWT). We consider three different satellite images and test each method on them. To determine the quality of the resulted fused image, we take four different measurements: The peak signal-to-noise ratio and entropy are calculated to determine the improvement of spatial resolution, while the coefficient correlation and spectral discrepancy are calculated to compare the amount of preservation of spectral characteristics. (Received September 17, 2013)

1096-Q1-2652 **David W. Roach*** (droach@murraystate.edu), Faculty Hall 6C-17, Murray State University, Murray, KY 42071. *Orthogonal Parameterized Wavelets in Undergraduate Research.*

In this talk, a simple parameterization of the entire class of one-dimensional orthogonal wavelets with dilation factor 2 will be presented. The construction of this parameterization is accessible to undergraduates from a theoretical perspective. Moreover, the parameterization itself allows for the exploration of various properties such as approximaiton properties or frequency response. The various parameterized wavelets can be compared with one another in an image compression scheme and a search can be made for the best orthogonal wavelet for a particular image through steepest decent and gradient search techniques. The necessity to search a multi-parameter space that is complex in structure allows the undergraduate student to implement robust programming algorithms such as simulated annealing or genetic algorithms. (Received September 17, 2013)

We Did More with Less: Streamlining the Undergraduate Mathematics Curriculum

1096-Q5-950 **Alison Ahlgren Reddy*** (aahlgren@illinois.edu). *Maximizing Student Outcomes with Minimal Resources in College Algebra at the University of Illinois.* Preliminary report.

At the University of Illinois all students scoring below 50 on the placement exam are placed into College Algebra. Thus students enter the course with very diverse mathematical needs and background knowledge. The challenge was to maximize student outcomes with minimal resources within the context of a single course. College Algebra was redesigned to a blended course: once a week large lecture, heavy use of ALEKS for learning and practice outside of class, and Piazza for communication. The redesign has been extremely successful in meeting the individual needs of all the students and we have seen improved success rates. As ALEKS adapts to each individual student's learning and needs some students will spend 120 hours in the system over the course of the semester, while others may spend 30. Piazza has been added for communication and class discussion. There are 200 students in lecture and they often feel anonymous and removed from the instructor. Piazza has provided a place for whole class discussions and for students to communicate directly with each other. Though we are teaching this course with less people, less time, and less resources, the student experience and outcomes are more. (Received September 11, 2013)

1096-Q5-1270 **Umesh P Nagarkatte*** (unagarkatte@yahoo.com), Chair and Professor, Dept. of Mathematics, Medgar Evers College, CUNY, Brooklyn, NY 11225, **Joshua Berenbom** (joshua@mec.cuny.edu), Department of Mathematics, Medgar Evers Collee, CUNY, Brooklyn, NY 11225, **Kay Lashley** (lashley357@yahoo.com), Department of Mathematics, Medgar Evers College, CUNY, Brooklyn, NY 11225, **Herbert Odunukwe** (hodunukwe@mec.cuny.edu), Department of Mathematics, Medgar Evers College, CUNY, Brooklyn, NY 11225, and **Lavoizier St. Jean** (ljean@mec.cuny.edu), Department of Mathematics, Medgar Evers College, CUNY, Brooklyn, NY 11225. *Adapting the Singapore Model Method of Problem Solving Framework to College Level.*

Singapore Mathematics and Science rank 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. The Framework is deeply rooted in underlying mathematics principles of effective problem solving methods, that is represented in a pentagon of interrelated components: Concepts, Skills, Processes, Metacognition, and Attitudes. 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. TOC is used to transcend the student from pictorial to logical thinking approach showing the logical connection between the assumptions and the unknown/s. (Received September 14, 2013)

1096-Q5-1279 **Carren S Walker** (carren@me.com) and **Joan M Zoellner*** (jzoellner@clark.edu). *Inverting the Classroom on a Tight Budget.*

Is it possible to implement innovative teaching strategies when minimal financial support is available? The authors have successfully inverted an Algebra 1 class at Clark College in Vancouver, WA under exactly these conditions. The project began through participation in a state-level grant with the goal of improving the success rate of this students taking Algebra 1, and to increase the likelihood that the students would subsequently take and pass a college-level math class. Working together to develop materials for the course and volunteering in each other's classes facilitated the implementation and fostered the student support necessary to test and improve the instructional materials. Various block schedules and delivery methods within the contact-hour restrictions of the college were investigated. Experimentation with open-source online support for the class was attempted, and the best support for student learning was while engaged in a pilot program testing a new non-profit online resource. The educational philosophy supporting the classroom shift, barriers encountered during the 7-quarter process, and cost-effective methods used to overcome those barriers will be discussed. (Received September 14, 2013)

1096-Q5-1851 **Joanne Peeples*** (joannep@epcc.edu). *Activities That Help Understanding – That Cost the College Nothing!* Preliminary report.

There are many little "projects" I have my students do in hopes of increasing their understanding (and love) of mathematics. My newest project involves writing instructions, and having another student follow the instructions. By having to write instructions, the student sees how important it is when working a problem to be very clear about what s/he does. To write a proof, one must be logical and clear – much like writing instructions. I'd like to share some of their work. (Received September 16, 2013)

1096-Q5-2451 **John R Wilkins*** (jwilkins@csudh.edu), Mathematics Department, California State University, Dominguez Hills, 1000 E. Victoria, Carson, CA 90747. *Improving success rates in developmental math with existing resources.*

Since the Fall 2008, the percent of first-time freshmen completing their developmental math requirement was 55%. By the Fall of 2011, the percentage was 77% and continues to rise. To emphasize the significance of this trend, these freshmen were determined to need development math by an Entry Level Math exam. This was accomplished in the beginning with very little additional funds. But with the improved results, grants were extended and the university funded an expansion of the operation. Three changes in practices occurred since 2008. First, department-wide tests were aligned to the curriculum and close attention was given to their validity and reliably. Each test was analyzed by item and feedback was given to the instructors. Second, based on tests results, instructors with consistently high class averages were consulted for their practices in class. These were then shared and syllabus and calendars were changed. Lastly, we worked with Division of Student Affairs to leverage their resources by extending the summer bridge model into the academic year. (Received September 17, 2013)

General Session on Assessment and Outreach

1096-VA-462 **Caitlin Phifer*** (caitlin@math.uri.edu) and **Jessica Libertini**. *A Remediation Program for Calculus: Initial Findings.* Preliminary report.

As with many institutions, URI's math program is faced with the challenge of teaching mathematics to students who lack the necessary background to succeed. In an effort to help students and instructors identify and target individual student weaknesses, URI's Calculus I course has piloted a competency-based precalculus remediation program. The goals of this program are to help students see the value of the prerequisite material and to offer learning and assessment opportunities to demonstrate proficiency. We will present early data on the program, discuss its efficacy, and share our ideas for future development. (Received September 17, 2013)

1096-VA-871 **Tharanga Mahesh Kumara Wijetunge*** (tharanga.wijetunge@lyon.edu) and **Dennis St. John**. *Evaluating student understanding and role of the Student Response Systems: What pre-service teachers say?*

Various pedagogical tools can be used to enhance students' learning and understanding. After learning some mathematical concepts, it is important to evaluate individual student understanding as well as whole class understanding. Formative and summative assessment tools can be used to evaluate such student understandings. If a teacher can understand each student's difficulties, if they exist, then the teacher can address those issues before the class moves on to a new concept or skill. In such cases, formative assessment tools can be extremely valuable. A set of per-service teachers participated in a study, where they used Student Response System (SRS) during their methods course. Pre-service teachers' initial understanding about formative assessment techniques was evaluated during the initial interviews. After they used SRS in their methods course, their perspectives about the formative assessment techniques were collected during the second and third interviews. Did their perspectives change? How did the use of SRS shape their perspectives about the formative assessment? By examining per-service teachers' reactions to interview questions, we are hoping to understand the role of the SRS and per-service teachers' perspectives about the formative assessment techniques. (Received September 10, 2013)

1096-VA-1160 **Susan E Kelly*** (skelly@uwlax.edu), University of Wisconsin - La Crosse, Mathematics Department, 1725 State Street, La Crosse, WI 54601. *Girls in Science: 15 Years of STEM Outreach for Middle School Girls.*

The summer of 2013 marked the fifteenth anniversary of the Girls in Science program at the University of Wisconsin – La Crosse. The program began as a partnership with faculty from the College of Science and Health and the office of Continuing Education and Extension(CEE). From the beginning, math and science faculty worked with members of the CEE office to create a weekend summer program that would offer middle school girls hands-on math and science workshops lead by faculty at the University. The program has had continued success and reaches girls from across the State and surrounding area. This talk will be given by one of the science directors since the program's conception. The talk will present the design and goals of the program. Practical matters such as advertising and budgeting will also be discussed. Sample workshops both in math and other sciences will be given along with some student perspectives of these workshops. The program has already reached about 600-700 girls and we hope this early outreach draws more young women into math and science fields. (Received September 13, 2013)

1096-VA-2272 **Galen E. Turner III*** (gturner@coes.latech.edu). *An index to aid in the development of High School recruitment of future Engineering and Science students.*

In this presentation, we showcase an index to aid institutions of higher education to better target professional development programs for high school teachers and recruitment of students. In particular, we propose an index, f, of an institution of higher education, defined as the number of feeder high schools who have graduates enrolling in the institution $\geq f$, as a useful indicator for the selection of high schools with whom an institution should work in the areas of professional development and recruitment of students. Using this f-index for the College of Engineering and Science at Louisiana Tech University, this presentation will show how professional development programs with regional high schools have positively impacted student enrollment in our engineering and science degree programs. (Received September 17, 2013)

1096-VA-2608 **Colm Mulcahy***, colm@spelman.edu, and **Bruce Torrence** and **Eve Torrence**. *Martin Gardner's Outreach in his Centennial Year: Mathematics Awareness Month 2014.*

The theme of Mathematics Awareness Month next April is "Mathematics, Mystery and Mystery", the title of a landmark 1956 book by Martin Gardner (1914–2010). It's an entirely appropriate acknowledgement of the legacy of the man who introduced so many generations of people worldwide to recreational mathematics from the mid 1950s on, through his highly influential Scientific American columns and associated books.

We'll discuss some of the highlights of the upcoming celebrations, as the MAA takes the lead on Mathematics Awareness Month in 2014 by offering extensive web resources and materials. Mathematics departments and teachers in institutions around the U.S. use MAM as an opportunity to promote awareness of mathematics by facilitating special lectures, events, and assorted engaging activities. (Received September 17, 2013)

1096-VA-2760 **Shenglan Yuan*** (syuan@lagcc.cuny.edu), 31-10 Thomson Ave., Long Island City, NY 11101, and **Yelena Baishanski** and **Reem Jaafar**. *Undergraduate Research Activities for Two-year College Students.*

Can students at a two-year college engage in mathematic research? What kind of research is suitable for students at such a school? To find out, the faculty advisors of the Student Math Society of LaGuardia Community College have recruited interested students to participate in the Maximizing Mathematics Achievement (MaxiMA) Project. Though every student at a community college must take math courses, there are no real opportunities for them to explore mathematics, or have any idea what mathematic research is. The advisors hope that, with carefully designed projects, students will get a taste of math research and perhaps even discover something new. There are currently four students looking into areas such as population dynamics, taxi geometry, and Ramsey theory. I'll talk about the student's experience, enthusiasm, and progress with their projects. (Received September 18, 2013)

General Session on Calculus

1096-VB-176 **Girija S Nair-Hart*** (girija.nair-hart@uc.edu), Girija Nair-Hart, 4200 Clermont College Drive, Batavia, OH 45103. *Concept Modification: A Teaching Experiment.*

I investigated cognitive processes that facilitate concept modification in Calculus II students by means of a small scale teaching experiment which was informed by the constructivist theory of learning. According to this theory, students learn best when they actively construct knowledge. Piaget stated that students' minds are not blank slates and that residues from previous incomplete concept images complicate the proper accommodation of new concepts. Therefore, to facilitate concept reform, students need to process the information and reach equilibrium by themselves. During my research, I realized that the process of knowledge equilibration could be expedited through a series of actions that pose cognitive conflict. I argue that concept modification could materialize if students are given the opportunity to interact with the concepts from multiple perspectives and then engage in refining that knowledge through debate and negotiation of meanings. I propose that by modifying traditional classroom settings to that of a constructivist classroom, students could be motivated to actively construct and refine mathematics knowledge. During the presentation, I will provide details of perceived concept modification by describing the events that occurred during a problem solving exercise. (Received August 13, 2013)

1096-VB-809 **Paul Sisson***, paul.sisson@lsus.edu, and **Tibor Szarvas**. *Teaching Calculus through History, Intuition, Exploration, and Development (HIED).*

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, describe their approach in the classroom and in their textbook as teaching calculus through the use of History, Intuition, Exploration, and Development (HIED). These four themes allow students to learn calculus by making connections with what they already know, what they suspect to be true, what they discover through the use of technology, and what they logically develop with the guidance of the professor and each other. (Received September 10, 2013)

1096-VB-961 **Jaewoo Lee*** (jalee@bmcc.cuny.edu), Department of Mathematics, Borough of Manhattan Community College, 199 Chambers Street, New York, NY 10007. *Introducing a proof on Fibonacci numbers to Calculus I students.*

We will present a student project which incorporates Fibonacci numbers and the concept of limit. It starts with students' experiments with Maple, which lead them to conjecture what will happen. We will discuss a false proof, what can be learned from it, and a simple correct proof. (Received September 11, 2013)

1096-VB-1134 **Alison Ahlgren Reddy*** (aahlgren@illinois.edu) and **Marc A. Harper** (marcharper@ucla.edu). *Identifying Concepts Critical for Success in Calculus at the University of Illinois.* Preliminary report.

Detailed data on students mathematical preparedness obtained from the placement program at the University of Illinois allowed a redesign of the university's precalculus course to better prepare students to be successful in Calculus I. The theory of knowledge states and placement assessments can be used to determine which of 200 topics and problem types are strongly associated with student course outcomes.

Our analysis detects the mathematical strengths and weakness of the students entering and exiting the precalculus course with unprecedented specificity, and in several topic areas, such as trigonometry. The results of our study were used to modify curricular emphasis in the course. Placement assessments for Calculus I students identifies predictive concepts for success in Calculus I, and the precalculus course was further modified to place additional emphasis on these important topics.

Entry and exit student data for precalculus will be shown highlighting key concepts for Calculus I success. The data also allows comparison of the students who enter Calculus I directly their first year versus those who take our precalculus course. Identifying the critical concepts for success has enabled us to better students to compete with those who enter Calculus I directly. (Received September 13, 2013)

1096-VB-2200 **Michael A. Jones*** (maj@ams.org), Mathematical Reviews, Ann Arbor, MI 48103, and **Jennifer Wilson** (wilsonj@newschool.edu), Eugene Lang College, The New School for Liberal Arts, New York, NY 10011. *Adjusting Child Support Payments in Michigan.*

Michigan uses an unusual formula in the calculation of child support payments. For divorced parents A and B in Michigan, the base monetary support each parent is expected to contribute to raising their child is adjusted according to the number of (over)nights spent with the parents. Curiously, this adjustment is based on a rational polynomial function parameterized by k that describes the amount of money that A must pay B, where B must pay A if the result is negative. In the 2004 Michigan Child Support Formula Manual, $k = 2$, meaning the polynomials are quadratic; while $k = 3$ (for cubic polynomials) in both the 2008 and 2013 editions. In this talk, we use calculus to examine this function, explain the effect of changing k, and point out an alternative form that stretches and translates a simpler function. (Received September 17, 2013)

1096-VB-2290 **Stephen M. Walk*** (smwalk@stcloudstate.edu), Dept. of Mathematics & Statistics, ECC 139, St. Cloud State University, 720 4th Ave. S., St. Cloud, MN 56301. *Faculty Learning Community Experience: Using Multidisciplinary Applications in Calculus Teaching.*

Last year, the presenter was involved in a Faculty Learning Community (FLC) with colleagues from mathematics and various other disciplines. The objectives were (a) to develop course materials to pique students' curiosity about the use of calculus in their own and other disciplines and encourage deeper understanding of the course concepts, and (b) to promote interdisciplinary cooperation. Assessment results from the use of these materials in the classroom, as well as reflections on the FLC experience, will be shared in this talk. (Received September 17, 2013)

1096-VB-2379 **Fabiana Cardetti*** (fabiana.cardetti@uconn.edu), **Nicole DeMatteo**, **Jonathan Dollar** and **Gabriel Feinberg** (gfeinberg@haverford.edu). *An Inquiry-Based Approach to Teaching Parameterization.*

Parameterization of curves has been identified as a challenging topic for students in multivariable calculus courses. Encouraged by the positive research results of inquiry-based learning (IBL) on student performance and attitudes, our team composed of mathematics professors and undergraduate math students conducted a research study to develop curricular materials aimed at supporting student understanding of this topic. For this study we conducted an extensive literature review, studied popular multivariable calculus textbooks, and consulted with experienced instructors to create an original IBL module. In this talk we will present the details of the module that engages students in collaborative discovery to gain a deep conceptual understanding of parameterization in addition to providing opportunities for procedural practice. (Received September 17, 2013)

1096-VB-2546 **Jody Sorensen*** (sorensj1@augsburg.edu). *From reddit to Calc III: How a picture led to a collaborative class project.*

Inspired by a picture found online, I worked with my multivariable calculus students to create simple 3D paper models of a variety of functions of two variables. I will share lessons in how to construct such models and what the students and I learned from them. (Received September 17, 2013)

General Session on the History and Philosophy of Mathematics

1096-VC-91 **John C.D. Diamantopoulos*** (diamantj@nsuok.edu) and **Cynthia Huffman Woodburn** (cwoodburn@pittstate.edu). *Techniques from the Ancients for Verification of Right Angles.*

Right angles have played an important role as long as there has been architecture, construction and surveying. In this presentation, we'll take a look at several ways that ancient peoples used basic, readily available materials such as knotted cords and pegs to lay out right angles prior to the advent of more technological tools. Methods will range from the well-known use of a 3-4-5 triangle by the Egyptians to a lesser-known Mayan technique involving three equilateral triangles. The various techniques will be shown via a hands-on demonstration that can easily be adapted for classroom use. We'll also show videos of successful implementation with a high school audience. (Received July 23, 2013)

1096-VC-329 **Tim Doyle** (doyletj@whitman.edu), **Lauren Kutler**, **Robin Miller** and **Albert Schueller*** (schuelaw@whitman.edu), 345 Boyer Avenue, Whitman College, Walla Walla, WA 99362. *On Proofs Without Words and Beyond.*

We discuss the history of the Proofs Without Words feature of the MAA's *Mathematics Magazine* and *The College Mathematics Journal* periodicals. We provide a philosophical context for the consideration of these mathematical artifacts as "proof" through the lens of Gottlob Frege's *The Foundations of Arithmetic*. We demonstrate several on-line, interactive, adaptations of selected Proofs Without Words that we have created. We argue that these on-line, interactive visual proofs are the next logical step in the evolution of Proofs Without Words. (Received August 28, 2013)

1096-VC-568 **William Zachary Wallace*** (wzwallace1@catamount.wcu.edu). *Thomas Leybourn and The Mathematical Repository.* Preliminary report.

The introduction of Continental approaches to the calculus in early nineteenth-century Britain was a controversial and revolutionary process. The associated printing presses of mathematical journals were booming with different publications centered on traditional British mathematics. Thomas Leybourn, along with his companions at Royal Military Academy at Marlow, was one of the first mathematicians who introduced continental methods through the medium of journals during this Golden Age of printing. In this talk, we will discuss different elements of Leybourn's journal, *The Mathematical Repository.* These elements include how it was founded, its format, key contributors, the audience of the journal, and how it was influential to the adoption of continental calculus methods in early nineteenth-century Britain. (Received September 06, 2013)

1096-VC-696 **Ellina Grigorieva*** (egrigorieva@twu.edu), PO BOX 425262, Denton, TX 76204. *Methods of solving complex problems: history of mathematics approach.*

Problems solved by ancient mathematicians very challenging and their different versions appear on some exams and math contests. This presentation will emphasize important and sometimes overlooked topics on triangles, quadrilaterals and circles such as Menelaus-Ceva theorems or Simson line, along with their proofs. You will be able to dissect a segment in the Golden ratio, construct an angle of 36 degree and visualize Fibonacci number. We will prove the inequality between geometric, arithmetic and harmonic means in pure geometric way, the way it was done 1000 years ago by ancient Greeks and prove why not every angle can be trisected using modern methods. You will learn which quadrilateral with given diagonals has the maximum area and solve unusual problems involving cyclic quadrilaterals and problems on location of circles and polygons with respect to each other. Moreover, it will be demonstrated how methods and "tricks" from elementary mathematics can be used in solving "hard" problems of undergraduate and graduate mathematics, such as differential equations, analysis and number theory. (Received September 09, 2013)

1096-VC-1018 **Rosanna Iembo*** (rosannaiembo@libero.it), via Federico Cozzolino 18, 84018 Scafati, Salerno, Italy, and **Irene Iaccarino** (irene.iaccarino@hotmail.it), via Interna Marina 19, 88900 Crotone, Italy. *And Cantor said to God: I come away with You.*

I do not know when this "way" began, this long and suffered "way" of Cantor on the "stair" of the infinity, of the infinite God. Soon each of us will think of Kronecker and of his acts and arguments against Cantor, though he was his student Why Kronecker did it, none of us is able to explain. Maybe we need to search in meanders of the heart, meanders full of virtues, but also of vices, of those terrible seven vices , defined -not by chance-deadly sins. Surely the innovations are always arduous and risky Therefore it is easy to think of the vicissitude of Cantor as a story with an expected end, an already played script. But it is not. This is another story. Not for the hatred of Kronecker, fierce still more because unjustified : this is always, unfortunately till now; but because Cantor, in spite of his human weakness, was able to read his terrible and ravaging experience in a new light. Cantor went so far as to thank God who did not fulfil his wish : a professorship in a prestigious university. In fact, only in this way, his mind might open to "true" yearning, might open to God. Yes, this is really another story. This is a love story, the story of the Infinite Love. (Received September 12, 2013)

1096-VC-1616 **Ximena Catepillan*** (ximena.catepillan@millersville.edu), PO Box 1002, Millersville, PA 17551, and **Cynthia Taylor**, PO Box 1002, Millersville, PA 17551. *A Kin Relations Lesson in Ethnomathematics: A Tribute to Marcia Ascher.*

The Warlpiri, a native Australian Northern Territory group, have a unique kin system to distribute their tasks and determine their roles in the society. The kin system created by these people has eight subsections and it is a mathematical model that we call a Dihedral Group of order 8. In this presentation a sample lesson taught at Millersville University will be introduced with exercises.

"Ethnomathematics: A Multicultural View of Mathematical Ideas" by Marcia Ascher (Received September 16, 2013)

1096-VC-1713 **Robert Rogers*** (robert.rogers@fredonia.edu), Department of Mathematical Sciences, SUNY Fredonia, Fredonia, NY 14063. *The Development of Algebraic Symbolism for Pre-service Teachers.*

The author will present his ideas for teaching an upper level history of mathematics course required for all middle and high school level pre-service mathematics teachers at SUNY Fredonia. This course focuses on the development of algebraic symbolism to solve classic word problems. By comparing classical techniques to modern symbolic methods, it is intended that these pre-service teachers gain an appreciation for how their future students might develop their own understanding of symbolism and problem solving. (Received September 16, 2013)

1096-VC-1896 **James F Kiernan*** (jkiernan@brooklyn.cuny.edu), Mathematics Department, 2900 Bedford Avenue, Brooklyn, NY 11210. *A Course to Address the Issue of Diversity.*

Brooklyn College is now offering an upper level CORE course entitled "The Mathematics of Non-Western Civilizations". The course is offered to all students who have completed a number of lower level CORE courses. The original course designed by Jeff Suzuki was based on readings from Katz' "Sourcebook" (2007). Several instructors in the department have now taught the course.

Since the recent publication of a third edition Joseph's "The Crest of the Peacock"(2011), I have successfully used it as the main text in the course.By using this text students become acquainted with concepts such as Eurocentism and Ethnomathematics in addition to learning some elementary mathematics developed in civilizations which are frequently neglected.

This talk will discuss issues regarding teaching a course on the diversity of mathematical development to a diverse population with diverse abilities. Examples of syllabi, assignments and assessments will be provided. I hope that this presentation will lead to some fruitful discussion of using history of mathematics in your classroom. (Received September 16, 2013)

1096-VC-2137 **Salar Alsardary*** (s.alsard@usciences.edu), 600 South 43rd Street, Philadelphia, PA 19104, and **Mohammad Haraaz**, Philadelphia, PA 19104. *Contribution of the Muslim Scientists in the field of mathematics.*

In this presentation, we will shed some light on the contribution of early Muslim scientists to the field of science in general and to mathematics in particular. We will start by presenting the scientists, their main field of contribution, where they lived and when they died. We will focus our attention towards two of the most successful and well known scientists during the Muslim golden age; Mahammad ibn Mosa Al-Khwarizmi and Nasir al-Din al-Tusi. (Received September 17, 2013)

1096-VC-2565 **Jean W Richard*** (jrichard@bmcc.cuny.edu), 199 Chambers St, New York, NY 10007, and **Hong Yuan** (hyuan@bmcc.cuny.edu), 199 Chambers St, New York, NY 10007. *History of Applications of Operations Research (Yun Ch'ou Hsueh) Methods in China (1958 - 1960).*

This presentation will explore how certain concepts of Operations Research "Yun Ch'ou Hsueh" were introduced to farmers and industrial workers in the People's Republic of China around 1960. The chosen mathematical methods the simplex method (called the tableau method in China) and the graphical method (called the diagrammatic operational method) though theoretically complex were easily taught to farmers and workers. Both methods required the basic operations of addition, subtraction, multiplication, and division, and were extensively applied during that period. The mathematical methods were used in different types of situations such as mail distribution, transportation, communications, agricultural production, and commodity distribution. Examples of how the methods were used in transportation will be presented. It was during this period of intense use of concepts of Operations Research in China that at Ch'u-Fou Normal College, Shandong that the method called "Chinese Postman Problem" was created. This problem has many applications, for example, in sanitation for the planning of street maintenance, in robotics, and website usability. (Received September 17, 2013)

General Session on Interdisciplinary Topics

1096-VD-533 **Johannah M Miller*** (johannah.miller@my.minotstateu.edu) and **Narayan Thapa** (narayan.thapa@minotstateu.edu). *Modeling the Energy Level of Hydrogen Using the Schrödinger Equation.*

The Schrödinger equation models the state of a hydrogen atom (that is, the behavior of its orbiting electron) with respect to position and momentum. We use the Heisenberg uncertainty principle to focus on the position of the hydrogen electron. The Time-Independent Schrödinger Equation (TISE) is then solved by the method of separation of variables. Three integral quantum numbers are derived using various calculus techniques, in addition to probability density function and normalization. The energy levels of the hydrogen atom are modeled as a function of n, the principle quantum number. The convergent result is shown analytically and numerically. (Received September 05, 2013)

1096-VD-1164 **Veera Holdai*** (vxholdai@salisbury.edu) and **David Eric Cowall** (cowall@comcast.net). *Patients with Advanced Cancer and their Survival in a Rural Community: The Impact of Hospice Services.* Preliminary report.

The intensity of end-of-life cancer care in a rural community has been previously reported using a random sample of all cancer deaths from Wicomico County, Maryland for calendar years 2004-2008. Statistical analyses of longevity and the impact of hospice services were performed. The log-rank analyses and hazard ratios were used to compare the life times from diagnosis to death between different groups of patients (whether they were referred to hospice or not; lung cancer etc). Prolonged survival was significantly associated with hospice services in our sample. (Received September 13, 2013)

1096-VD-1767 **Breanne M Hatfield*** (breanne.hatfield@my.minotstateu.edu) and **Narayan Thapa** (narayan.thapa@minotstateu.edu). *Parameter Estimation of Tumor Growth Model.* Preliminary report.

This talk outlines a number of mathematical models describing avascular tumor growth. Taking into consideration the location of a cell within a tumor, we examine cell proliferation and death. Both numerical and analytical solutions are derived. Model parameters are estimated by using simple inverse problem techniques. (Received September 16, 2013)

1096-VD-2425 **Kristin McCullough*** (kmccullough@grandview.edu), **Nader Ebrahimi** (nader@math.niu.edu) and **Zhili Xiao** (zxiao@niu.edu). *Modeling the Reliability of a Hydrogen Gas Nanosensor.*

Nanosystems have great potential in practical applications, such as significantly enhancing the performance of gas detecting sensors. Much research has been devoted to designing and fabricating these nanosystems, while the question of reliability has been overlooked. Here we focus on the reliability of one specific hydrogen gas nanosensor based on a network of ultra-small palladium nanowires. Unfortunately no data is available for reliability analysis, so we rely on a computer model to simulate the behavior of the nanosensor over repeated exposures to hydrogen gas. Using various lattices to represent the structure of the network, we evaluate the reliability, both analytically and through simulations, using site percolation. We attempt to resolve many of the unique difficulties that arise due to the small size and unique properties of the nanowires. (Received September 17, 2013)

General Session on Mathematics Education

1096-VE-17 **Jeevan Kumar Neelam*** (neelamkushalaiah@gmail.com), 19-6-194, Rangashaipet, Warangal, India 506005, India. *Jeevan Exp-Log Method for Real, Imaginary and Complex Homogeneous and Non-Homogeneous Polynomial Equations.* Preliminary report.

The Abstract Title of the paper explains about the Real, Imaginary and Complex Polynomial equations.This is one Mathematical logical method to find root of any polynomial Equation irrespective of Nature and Type Constants and Powers.Comparision of the method deals with famous method,"BEDMAS"-Technique. (Received April 23, 2013)

1096-VE-39 **Ronald L Merritt*** (ronald.merritt@athens.edu), 300 North Beaty Street, Athens, AL 35613. *The genesis of a mathematics learning community from a mathematics tutorial center.*

Although the Mathematics Lab has been in existence at Athens State university for several years, perpetual alterations to the program that have been implemented since the spring semester of 2009 have spawned the development of a mathematics learning community. Each semester the Mathematics and Programming Lab undergraduate staff members host hundreds of visits from students majoring in a variety of disciplines who either need assistance with their undergraduate mathematics courses ranging from liberal arts mathematics through junior level mathematics courses, and more recently students who, since the summer of 2011, require assistance with elementary computer programming. Planning, development, evaluation, efficacious and periodic self-study, recruiting and meaningful orientation, and effective advertisement are some factors among others which have made the Mathematics and Programming Lab a success over the last several years and have likewise encouraged the development and augmentation of successful mathematics communities. The atmosphere and service provided by the Mathematics and Programming Lab have attracted numerous mathematics and mathematics education majors and provided them with a centrally unique area of cooperative learning, sharing of ideas and study. (Received June 10, 2013)

1096-VE-46 **Mark L. Daniels*** (mdaniels@math.utexas.edu), Mathematics Department, 2515 Speedway Stop C1200, Austin, TX 78712. *Creating a Dual-Credit/Dual Enrollment "OnRamps" Precalculus Course to Enhance the College Readiness of High School and Community College Students.* Preliminary report.

The creation of a dual credit or dual enrollment "OnRamps" Precalculus course for High School or Community College students is discussed. Such a course is intended primarily to enhance the calculus and college-readiness of high school students. The course stresses "college level thinking" and is designed to be taught in a discovery way using inquiry-based teaching methods. An online component that accompanies the course will also be detailed. (Received June 13, 2013)

1096-VE-77 **Bethany Noblitt*** (noblittb@nku.edu) and **Brooke Buckley** (buckleyb1@nku.edu). *Organizing a Middle Grades Summer Math Camp with Pre-Service Teachers.*

This presentation will describe a three-week summer experience for pre-service mathematics teachers during which a mathematics camp for middle grades students was planned and implemented. The pre-service teachers were a mixture of Noyce scholars and summer interns. Noyce scholars were juniors, seniors, and alumni who have received scholarship funds through the NSF-sponsored Robert Noyce Scholarship program. Interns were incoming freshmen or rising sophomores who had expressed interest in teaching mathematics. The first two weeks of the summer experience were spent with the scholars and interns doing mathematics, planning daily activities for middle grades students, and investigating Common Core State Standards related to those activities. The third week of the experience was the implementation of the summer camp with 13 middle grades students from the northern Kentucky region. During the presentation, presenters will discuss their experience facilitating the planning of camp, as well as feedback received from the scholars and interns. Those in attendance will learn about a potential experience to engage their mathematics education students in an authentic learning environment. (Received July 12, 2013)

1096-VE-87 **murray h. siegel*** (murray.siegel@asu.edu), Math & Science Faculty, SLS, Polytechnic Campus, Mesa, AZ 85212. *Alternate Base Arithmetic as a Tool for Preparing Future Elementary Teachers.*

Many math texts used to prepare elementary teachers include a chapter on alternate bases. Typically the focus of this chapter is on translating from one base to another. Actually having pre-service teachers perform calculations using alternate bases is an effective method to heighten understanding of arithmetic operations and allows future teachers to empathize with difficulties students may have when learning whole number operations. Students are introduced to base 5 and prepare a base 5 addition table. This table is used to complete addition and subtraction computations in base 5. Since multiplication is repeated addition, the addition table is used to create a base 5 multiplication table. That is used for multi-digit multiplication problems. Both tables are used to perform long division exercises. Students are then introduced to other bases, including base 12. At some point many students find the computations difficult. It is then pointed out to the class that they are having difficulties even though they have mastered whole number arithmetic. Students are asked to "remember this moment" when dealing with the frustrations expressed by your future students. There are some very appealing side topics. Is 3113 odd or even in base 5? How about 1134? (Received July 18, 2013)

1096-VE-123 **Grace L. Coulombe*** (gcoulomb@bates.edu), 3 Andrews Road, c/o Ladd Library, Lewiston, ME 04240, and **Mary B. O'Neill** and **Michael E. Schuckers**. *Quantitative and Mathematics Support Centers: Update from the National Science Foundation Workshop.*

Quantitative and Mathematics Support Centers (QMaSCs) exist in one form or another at nearly every two and four year college and university in the United States. These centers provide help to large numbers of students and are pivotal in keeping students in the Science, Technology, Engineering and Mathematics (STEM) pipeline and in developing a future work force with the required tools for tackling STEM problems, but they often serve students outside of STEM to broaden quantitative compentency in the arts, humanities and social sciences. The work of the QMaSCs is focused primarily on assistance for students in undergraduate courses. Leadership and administration of these centers take a variety of forms with some led by tenure-track faculty, others by part-time or full-time staff. While QMaSCs perform a critical academic support function, little is known about them at a national level. Further, there is not an infrastructure for the discussion of center issues or the dissemination of resources to guide directors of QMaSCs, particularly those just starting in that role. In this paper we will present an update on a handbook for QMaSC directors, one of the primary outcomes of a recent National Science Foundation workshop. (Received August 01, 2013)

1096-VE-288 **Qingxia Li*** (liq@lincolnu.edu), 701 S Providence Road, Apt 1I, Columbia, MO 65203. *Alternative Teaching Strategies in Pre-Calculus.*

In Calculus courses, student have a lot of difficulties in understanding the core and confusing concepts which they have learned in their pre-calculus courses. In order to improve the student success in Calculus classes, I was supported by a NSF grant (AMASS) to examine alternative teaching strategies to help students understand the core/confusing concepts. In my pre-calculus class, I added student presentations in my study. The study used a quasi-experimental non-equivalent control group design. The independent variable was the course type (Baseline Group and Experimental Group). The Baseline group consisted of the data such as the retention rate and grade distribution collected from the academic year 2011-2012. The Experimental group was the data collected from Fall 2012. By comparing the data collected from these two groups, students from Experimental group were expected to show an increase in retention rate and passing rate. The main objective of this project are to get students to be prepared for upper level mathematics courses that their majors might require.In this presentation, I will demonstrate the data collected for this study, discuss the strengths and weakness of this project, and provide some future suggestions for similar projects. (Received August 26, 2013)

1096-VE-354 **Diana S Cheng** (dcheng@towson.edu), 8000 York Road, Towson, MD 21252, and **Rachel Jones*** (rjones39@students.towson.edu), 8000 York Road, Towson, MD 21286. *Divvying up the Practice Field: Student Solutions.*

We present a cognitively challenging partitioning problem that can be solved using geometry and algebra. In-service teachers' varied solutions are analyzed and described as non-generalizable and generalizable. While the problem can be solved using formulas for area, the problem can also be solved without using equations but using transformational reasoning. (Received August 29, 2013)

1096-VE-429 **Stan Yoshinobu*** (styoshin@calpoly.edu), 2230 Exposition Drive Unit 30, San Luis Obsipo, CA 93401. *Using Inquiry-Based Learning in Courses for Prospective Elementary Teachers.*

As schools transition to the Common Core State Standards, one way to prepare prospective elementary school teachers for the Common Core Math Practice Standards is to provide an immersive math experience. Such an experience includes deep engagement in rich, inquiry-based math tasks, opportunities to collaborate with peers, engaging in video lesson study, and journal writing to address attitudes and beliefs. This talk will provide an overview of an "all-inclusive" course structure, materials, and available resources. (Received September 03, 2013)

1096-VE-632 **Lynette D Guzman*** (guzmanly@msu.edu), 122 North Kedzie Hall, 354 Farm Lane, Michigan State University, East Lansing, MI 48824. *Providing opportunities for prospective teachers to engage in mathematical practice and mathematize situations outside of school mathematics.* Preliminary report.

Recommendations in *The Mathematical Education of Teachers II* (CBMS, 2012) suggest that prospective teachers (PSTs) should have opportunities to engage in Common Core State Standards for Mathematical Practice and "to mathematize situations by focusing on the mathematical aspects of a situation and formulating them in mathematical terms" (p. 33). These experiences support PSTs' learning and teaching of mathematics while expanding their capacity to support children's engagement in mathematical practice and learning of mathematics. By recognizing how children see and use mathematics in their communities, PSTs may draw on this information to make instructional decisions.

This project is part of a larger study that produced modules designed to teach PSTs to make stronger connections between children's mathematical thinking and children's outside of school experiences in mathematics lessons. This presentation will report examples of how making these connections in an elementary mathematics methods course encouraged PSTs to engage in mathematical practice and mathematize situations. We will also explore possible experiences college mathematics instructors could provide for future elementary mathematics teachers to expand their views on teaching and learning mathematics. (Received September 08, 2013)

1096-VE-651 **Steven J Boyce*** (sboyce@vt.edu). *Modeling the variations in students' coordination of units.*

I build off of descriptions of a hypothetical learning trajectory by which the students' reorganize their ways of thinking about number to coordinate additional *levels of units*. The number of levels of units are mathematics educators' constructs for characterizing the psychological structures necessary for a robust (elementary) understanding the rational number system - one in which improper fractions and negative integers are full-fledged members. For example, three levels of units are theorized as necessary for immediately understanding the fraction 7/4 as 7 iterations of 1/4, 4 of which would make 1. I describe an initial approach for modeling the variations within sixth-grade students' units coordinations across contexts by considering changes in students' *propensity* for attending to and coordinating an additional level of units. I look forward to feedback from others also seeking to apply mathematics to the teaching and learning of mathematics. (Received September 08, 2013)

1096-VE-851 **Atma R Sahu*** (asahu@coppin.edu), 7704 Mystic River Terrace, Glenn Dale, MD 20769. *Examining Math-Educators Preparation CAEP's first Standard and CCSS for Math Practice.*

Newly formed CAEP –"The Council for the Accreditation of Educator Preparation", will ensure that educator preparation providers (EPPs) prepare and graduate future teachers who know the content of the subject(s) they will teach, know how to teach that content effectively to students from diverse groups, and demonstrate their positive impact on P-12 student learning in diverse school settings. Accordingly, keeping in view the pedagogical aspects of knowing how to teach students mathematics, the coherence of CAEP's first Standard of educator preparation has been cross examined in this presentation, with the Common Core State Standards Mathematics Practice (CCSSMP) 1 to 8, and discussion is limited to the secondary mathematics content and teacher preparation level. Furthermore, the CCSSMP 1-8 content standards which set an expectation of mathematics instructional and conceptual understanding are potential 'points of intersection' of the Standards for Mathematical Content , Standards for Mathematical Practice , and CAEP's first standard The presenters will also discuss the necessity to qualitatively improve the instruction and professional development practices that merits the time, resources, and new energies invested in mathematics educator's preparation programs. (Received September 10, 2013)

1096-VE-901 **Mahmoud A Yousef*** (yousef@ucmo.edu) and **Shing S So** (so@ucmo.edu). *Improving the Quality of Instruction in Middle School Mathematics.*

Mathematics has earned a reputation as being particularly critical for student success beyond high school. In this paper, we will present an Inquiry-Based Learning methodology coupled with technology to increase success for middle school mathematics students. Specifically, we will provide information and sample classroom-ready activities and lessons from a three-week workshop for middle school mathematics teachers. (Received September 11, 2013)

1096-VE-914 **Aldo R Maldonado*** (amaldonado@park.edu), Austin, TX 78728. *What is the best approach to teach the Central limit theorem?*

In the introductory statistics course one of the central limit theorems is required almost right away. It is a "deep" concept. How do students not in the mathematical sciences deal with it ? Author will discuss a couple of different approaches that have failed and some that have succeeded in a private not-for profit large size university. (Received September 11, 2013)

1096-VE-1027 **Victor Kostyuk** and **Nathaniel Rounds*** (paulette.willis@reasoningmind.org), 2000 Bering Dr., Suite 300, Houston, TX 77057, and **Paulette N Willis**. *Distorted mathematics: what math education teaches students about math.*

Any system of math instruction invariably transmits beliefs about the nature of mathematics. Many American students come to believe that mathematics is a incoherent jumble of arbitrary rules. We discuss how math curricula can create a coherent picture of mathematics and inculcate productive beliefs about its learning and utility. (Received September 12, 2013)

1096-VE-1029 **Victor Kostyuk**, **Nathaniel Rounds** and **Paulette N Willis*** (paulette.willis@reasoningmind.org), 2000 Bering Dr., Suite 300, Houston, TX 77057. *Mathematicians and K12 curriculum development.*

Professional mathematicians' involvement in K12 education has ebbed and flowed over the past century. We discuss how mathematicians have influenced school curricula in the past, and mathematicians' current interest in shaping math education in the US. (Received September 12, 2013)

1096-VE-1059 **Soofia Malik*** (soofia.malik@unco.edu), 501 20th St., Ross Hall 2210D, College of Natural and Health Sciences, School of Mathematical Sciences, Greeley, CO 80639, and **Niloofar Ramezani** (niloofar.ramezani@unco.edu), 501 20th St.. , McKee 518, Campus Box 124, School of Educational and Behavioral Science, Department of Applied Statistics and Research, Greeley, CO 80639. *A comparison and contrast of undergraduate students' mathematics and statistics anxiety levels based on gender, college-year, major field of study, and mathematics background.* Preliminary report.

The present study investigated differences in statistics and mathematics anxiety levels based on students' gender, college-year, major area of study, and mathematics background of undergraduates enrolled either in introductory statistics course or in college algebra in a mid-sized doctoral granting university in the Rocky Mountain region of the US. The sample consisted of 309 students who volunteered to participate in this non-experimental survey study. Two modified versions of Mathematics Attitudes Scale (Fennema & Sherman, 1976) were used to measure students' statistics and mathematics anxiety levels. The internal consistencies of the survey items were tested using Cronbach's alpha and split-half reliability coefficients and were found to be extremely reliable. Statistical methods, such as, a one-way ANOVA and regression analysis were performed to analyze the data. The results revealed no statistically significant college-year differences on anxiety towards statistics and mathematics. However, mathematics background was found to be highly significant on both mathematics and statistic anxiety scores. Also, females indicated higher anxiety towards mathematics than males. This presentation will expand upon the results and future directions for this study. (Received September 12, 2013)

1096-VE-1084 **Sayonita Ghosh Hajra*** (sayonita@uga.edu), Department of Mathematics, Boyd GSRC, University of Georgia, Athens, GA 30605. *A comparison of the Common Core and the Indian Standards on Fractions.*

In this talk, I will report on the comparison of the syllabi and the textbooks of grades 1 through 7 of the Indian National Council of Educational Research and Training (NCERT) and the Common Core State Standards (CCSS) on Fractions. My study involved 9 students' interview (four from USA and five from India), which revealed some of the possible problems in the NCERT's syllabi and textbooks on fractions. Here, I will present those problems and some suggestions to NCERT to improve the standards on fractions in the Indian curriculum along with the comparison of the students' interview results from both the countries. (Received September 12, 2013)

1096-VE-1115 **Niloofar Ramezani*** (niloofar.ramezani@unco.edu), 501 20th St., McKee 518, Campus Box 124, Department of Applied Statistics and Research, University of Northern Colorado, Greeley, CO 80639. *The effect of early high school mathematics achievement on public schools' students' college ready performance in Texas.*

The Academic Excellence Indicator contains information on students' performance, which is one of the most important response variables in educational studies. Using the large dataset from Texas Education Agency, performance on college admission tests (ACT and SAT) and college ready graduates' percentage are used as indicators to measure college readiness as response variables and are compared based on the power of their models. The main goal is finding the effect of early high school mathematics achievement on public schools' students' college ready performance. By using "Incremental Partitioning of Variance" within a multiple regression for this longitudinal study, the models are fit over four years by entering variables in different orders. College ready performance is modeled based on students' mathematics scores over two years, annual dropout rates, and some demographic variables. Applying this method and some other Statistical analysis shows the relationship among variables and also the best indicator for this regression model which is ACT. For this study, these variables do a better job predicting ACT than the other response variables. For future research, these models and this dependent variable may be used for other groups of students using cross-validation methods. (Received September 13, 2013)

1096-VE-1130 **Dianna J. Spence***, UNG Department of Mathematics, 82 College Circle, Dahlonega, GA 30597, and **Brad Bailey**, UNG Department of Mathematics, 82 College Circle, Dahlonega, GA 30597. *Authentic Discovery Projects in Elementary Statistics: Implementation and Impact on Student Outcomes.* Preliminary report.

We describe teaching methods and materials developed to help elementary statistics instructors facilitate authentic discovery projects in which students actively engage in statistical inquiry in the context of a real-world application. We examine the distinguishing features of such projects, because not all projects qualify as "discovery projects". We describe a set of curriculum materials developed to guide instructors and students in the implementation of these projects and share access to these materials. We then share preliminary results from data collected around the country regarding the effectiveness of these methods and materials. These results include findings about impact on student learning and student dispositions, as well as different outcomes observed among individual instructors. (Received September 13, 2013)

1096-VE-1153 **Roger Mark Fischer*** (rfischer@math.montana.edu), 210 South Yellowstone, Apartment D, Apartment D, Bozeman, MT 59718. *Rational Numbers and the Common Core: A Descriptive Case Study.* Preliminary report.

Research suggests that middle grades teachers have a problematic sense of number. Of special concern is the well-documented tendency among these teachers to view the same number differently when its representation is changed. The Common Core State Standards for Mathematics calls for students to "develop a unified sense of number" (p. 46) and relies heavily on the decimal representation of rational numbers as a means to this end. The existing literature suggests that teacher are ill-equipped to develop a unified sense of number among their students.

The purpose of this study is to describe how a sample of middle grades teachers understands rational numbers, how they interpret a definition of rational numbers that relies on decimal representation, and how this knowledge manifests during instruction. Phase one of the study will involve a standardized open-ended interview with ten to fifteen middle grades teachers regarding their sense of rational number. Phase two will consist of observing this same group of teachers delivering lessons on repeating decimal concepts. Data will be analyzed using a multi-tiered approach of reading and memoing, describing the participants, setting, and participant actions, and classifying the data in a search for common themes. (Received September 13, 2013)

1096-VE-1158 **Natalie M Aviles*** (avilesnatalie@gmail.com) and **Magdalena Mulvihill**. *Strategies for teaching mathematics in a multicultural classroom.* Preliminary report.

In a secondary school classroom of culturally and linguistically diverse learners, teaching strategies can and should take these factors into account. We discuss approaches for adapting context-rich mathematics problems to these audiences, and various nontraditional ways in which students may participate and contribute in classroom activities. We believe that these methods will encourage students to increasingly engage with both the subject matter and their peers, leading to an improved educational experience for all. (Received September 13, 2013)

1096-VE-1343 **Raymond T. Boute*** (raymond.boute@pandora.be). *The bane of notation abuse and the endangered art of symbolic reasoning in mathematics education.* Preliminary report.

In prose, bad spelling is rarely accepted. In mathematics, notation abuse is often condoned. Excuses are worn. In education, bad notation is a disservice to students: annoying the bright ones (even if they cope), confusing others (subject to teachers' whims). Notation is not just language but a tool for effective thinking. Others noted how abuse causes errors, "easily undermining the students' confidence in mathematics". Examples are added, even about basic equality. It is shown how abuses can be avoided unobtrusively, helping mindful teachers to do everything right by example and making proper notation routine for students.

As a reaction to ill-conceived formalism in the 1960's, there is now overshoot in the other direction, and some mathematicians advocate using only prose, especially in "advanced" work. At frontiers, known tools may not always suffice, but rejecting tools should not be made a principle: symbolism is a later development phase and needs maturing. Bad notation causes a vicious circle. Especially for logic thought, the impracticality of classical formal logic is no reason for shirking but for improvement. Examples show the opportunities. Balance can be restored, so that prose and well-designed symbolism can coexist, as students have seen in algebra. (Received September 15, 2013)

1096-VE-1788 **Salvatore P Giunta*** (sgiunta@adelphi.edu), Department of Mathematics, 1 South Ave., Garden City, NY 11530. *Engaging student discussion outside the classroom using Twitter.* Preliminary report.

We discuss our experiences engaging students outside the classroom with Twitter, in courses for majors and for non-majors. We present context-rich questions that involve mathematical ideas and critical thinking, but which also, due to the 140-character limit, leave various details for the reader to fill in. Students must consider the main issue and distill their responses, forcing them to balance accuracy and brevity. This process also naturally extends to animated follow-up discussions at the beginning of class meetings, which transitions into a communicative class period. (Received September 16, 2013)

1096-VE-1793 **Priya V. Prasad*** (pvprasad@math.arizona.edu), 617 N. Santa Rita Ave., Tucson, AZ 85721. *Investigating the connections between content-based professional development and teachers' instructional choices.*

What do teachers gain from sustained, content-based professional development (PD)? Three case studies of teachers who underwent an algebra course at a university are presented. The aim of this research is to understand how teachers form connections between content presented in professional development and the content they teach in class. Currently, literature about PD only begins to address how such courses affect teachers' instructional choices in the classroom. After completing task-based interviews to map their content knowledge of algebra and being observed teaching those concepts in class, teachers contextualized this PD program within the greater narrative of their PD experiences. The connections teachers made between the PD content and classroom content could be classified as direct, indirect, and missed. These classifications characterize the new content knowledge that teachers' gained during PD. However, these connections were only one part of the greater picture of teacher development. Other mediating factors include fluctuating beliefs about mathematics, previous PD experiences, and mathematical confidence. This study aims to contribute to the body of knowledge about PD by beginning to connect teachers' experiences in PD with their instructional choices. (Received September 16, 2013)

1096-VE-1890 **Diana Suzana Mandar*** (suzanad23@yahoo.com), Jl. Seroja Raya No 3, Cengkareng, Jakarta, Indonesia. *Comparative of Stratified Alpha, Mosier, and Wang Reliability Coefficient.* Preliminary report.

Test should have high a reliability and a validity so that they can increase the accuracy in determining students' scores. Empirically, reliability is showed by reliability coefficient. The aim of this paper is to compare the Stratified Alpha reliability coefficient, Mosier reliability coefficient, and Wang reliability coefficient. In this paper, it uses multifactoring that is relating to the visualization capabilities, abstract logic, and analysis which are included in the field of Geometry, Calculus, and Algebra as part of Mathematics. Research data was taken from Education Research Center with a population of 5000 science program class III Senior Secondary School students in DKI Jakarta whose had done their National Exam in academic year 2010/2011. Based on this study, we found those Stratified Alpha reliability coefficient is less than Mosier reliability coefficient and Mosier reliability coefficient is less than Wang reliability coefficient. (Received September 16, 2013)

1096-VE-1939 **Sarah Mall Hanusch*** (sh1609@txstate.edu), 601 University Drive, San Marcos, TX 78666. *Using smart-pen technology to study problem solving.*

To analyze students' thought processes when solving novel problems, task-based interviews are often utilized. Often the field notes of task-based interviews are supplemented by audio or video recordings and the written work of the students being interviewed. An alternate to this is utilizing smart-pen technology which dynamically records written text and audio in the vicinity of the pen. As such, the smart-pen produces a document, called a pencast, which links what the student writes to what the student says at any moment.

Smart-pen technology was utilized in task-based interviews conducted in small groups of students from a large university. These students were asked to solve a problem that is typically solved using graph theory. However, the students selected were not introduced to graph theory definitions or concepts before being given the task.

This talk will address how smart-pen technology was implemented in order to document the task-based interviews and observations gleaned from the students' approaches to this problem. (Received September 16, 2013)

1096-VE-1986 **Manyiu Tse*** (mtse@molloy.edu), Molloy College, Mathematics and Computer Studies Department, 1000 Hempstead Avenue, Rockville Centre, NY 11571. *A Pilot Study on the Impact of Incorporating Problems with Incorrect Solutions into Exams on Students' Understanding of Mathematical Concepts.* Preliminary report.

Students often learn mathematics through examples that have been worked out, and are then tested with similar questions. However, correct solutions written by students are not always indicative of their understanding of the mathematical processes behind the problems. This can be shown by revising a studied example that is outside of a student's thinking box. One way to enhance the students' reasoning and math communication is to look at problems with erroneous solutions. To facilitate this study, five questions with incorrect solutions were embedded in an exam, and the students were asked to identify and explain each error. What follows is an analysis of the study. (Received September 17, 2013)

1096-VE-2047 **Jane Butterfield**, **Harvey Keynes**, **Jonathan Rogness** and **Justin Sukiennik*** (jesukien@colby.edu), Department of Mathematics and Statistics, 5853 Mayflower Hill Drive, Waterville, ME 04901. *A Continuing Study of Gender Difference on a Qualifying Exam.*

We examine the qualifying entrance exam for the University of Minnesota Talented Youth Mathematics Program (UMTYMP), a five-year accelerated program from high school algebra through vector analysis using linear algebra. The original 50-question, 20-minute exam, which assess computational, numerical reasoning and geometric skills, has accurately identified qualified students but with lower overall scores from females. We have extensively investigated the structure and content over the past several years to determine possible sources for these differences. In 2012, we made changes to improve the overall structure and content, and in the process, essentially eliminated the gender bias on one version of the entrance exam, increasing the percentage of females who qualified. The other 2012 unchanged versions showed the typical gender difference from previous years. We made similar modifications in an alternate version of the entrance exam for 2013 based on the 2012 exams, and several gender differences persisted in this newer version. Since the original version had different structural and content characteristics, we are continuing in our investigation to understand the sources and reasons for the differences while monitoring the overall student performance upon enter the program. (Received September 17, 2013)

1096-VE-2076 **Ali S. Shaqlaih***, University of North Texas at Dallas, 7400 University Hills Blvd, Dallas, TX 75241. *Inquiry Based Learning and Hybrid Inquiry Based Learning in College Geometry.*

Hybrid Inquiry Based Learning (HIBL) is a modified version of the Inquiry Based Learning model (IBL). It integrates the traditional teaching approach with the Inquiry Based Learning approach. A comparison of the two approaches (HIBL and IBL) will be presented and students' engagement, assessment and achievement in college geometry will be discussed in both approaches. (Received September 17, 2013)

1096-VE-2077 **Nermin Bayazit*** (nbayazit@gsu.edu), 30 Pryor Street Suite 609, Atlanta, GA 30303. *What Role Does (or does not) the Content Area Play in Proof Production Using Mathematical Definitions?*

This study investigated prospective secondary mathematics teachers' understanding and use of mathematical definitions in three content areas: set theory, linear algebra and geometry. Four secondary mathematics education students were individually interviewed four times to collect data. The focus of the first interview was on their perceptions of mathematics, mathematical definitions and proof. The other three interviews focused on their understanding of a given definition, use of definitions in doing proofs and assessment of the validity of a given proof that follows a direct application of a definition in the three content areas. The results of the study suggested that there might be a relation between students' perceptions of mathematics and proof, and their approaches to proof production. In addition to this, it has been observed that students' previous knowledge can inhibit their understanding of a given definition or using the definition to construct a proof. Lastly, students' familiarity with the content may not be an indicator of successful proof production within that area. (Received September 17, 2013)

1096-VE-2162 **Melissa L Goss*** (melissa.goss@unco.edu), 501 20th Street, Campus Box 122, Greeley, CO 80639, and **Rebecca Anne Dibbs** and **Robert Powers**. *Professional Development and Student Achievement on Standardized State Exams.* Preliminary report.

Although teacher quality is positively correlated with student achievement, easily quantified measures of teacher quality are not accurate measures of quality; teacher pedagogical content knowledge and skills are better predictors, but difficult to measure. Professional development may be a cost-effective vehicle for developing new skills in in-service teachers, but there is conflicting research on whether professional development measurably raises student achievement on high stakes standardized tests. The purpose of this causal-comparative study was to examine Andrew, an in-service, high school teacher participant in a master's program in mathematics. State mathematics assessment and student demographic data were collected from school districts for 4 academic years spanning from pre-program through program completion. One-way ANOVA analysis on student scale scores factoring by year showed a significant decrease in student mathematics scale scores potentially attributable to differences in population. Independent-samples t tests on the final two years showed a statistically insignificant increase in student growth percentiles. Further statistical analyses on 17 more teachers are being conducted presently. (Received September 17, 2013)

1096-VE-2203 **Jason Howell*** (howelljs@cofc.edu). *An Early Course on Modeling and Computation with Differential Equations.*

Traditionally, students gain minimal exposure to the modeling and solution of differential equations in first and second semester Calculus courses. In this talk I will discuss the design, implementation, and execution of a course in differential equations that can be taught after first-semester introductory differential and integral Calculus. The course is motivated by mathematical modeling and gives students early experience in using computational tools to compute approximate solutions to systems of differential equations. Another main focus of the course was on developing students' technical communication skills by requiring regular writing assignments and a final project in the style of a journal article and conference presentation (Received September 17, 2013)

1096-VE-2252 **Gabriel Feinberg*** (gfeinberg@haverford.edu), **Lily An**, **Victoria Lewis** and **Fabiana Cardetti**. *Resources to Aid the Transition into an IBL Mathematics Course.*

Inquiry-based learning (IBL) has been shown to deepen student cognitive and conceptual learning, as well as increase student engagement and motivation in a subject without affecting procedural understanding. The teaching and learning experiences in an IBL class are sufficiently different from traditional courses; however, there are few research-based resources to aid instructors and college students adapt to this approach. Thus, we conducted a study to support both instructors and students who are transitioning to an IBL course. The creation of these resources was guided by extensive review of the literature and was informed by instructors with experience teaching lower level undergraduate mathematics courses and students who had both positive and negative experiences in IBL courses. These methods, along with our own expertise as mathematics professors and undergraduate mathematics students, helped us identify specific aspects that are most challenging for an instructor and the difficulties students would face in transitioning to an IBL course. In this talk we will present the results of this study that consist of teacher's and student's guides that address those difficulties, provide guidance for each audience, and contribute suggestions to achieve the desired learning outcomes. (Received September 17, 2013)

1096-VE-2314 **Jesse C. Beck*** (jcb5b@mtmail.mtsu.edu), **Jennifer Yantz**, **Andrea R. Cline** and **Ginger Holmes Rowell**. *Lessons Learned from Students' Views on Algebraic Misconceptions for Precalculus Readiness.*

Middle Tennessee State University's Mathematics as a FirstSTEP to Success in STEM project is an NSF-funded project exploring mathematics interventions for first-time, full-time freshman STEM majors with math ACT scores between 19 and 23, inclusive. FirstSTEP students participated in a two-week Summer Bridge focused on increasing their readiness for precalculus. One component of this program was peer-led group sessions where the students engaged in tasks that used examples of student work to explicitly address common misconceptions related to specific mathematical ideas. These tasks utilized problems that required students to evaluate a series of correct or incorrect steps and to justify their conclusions by providing written explanations of their reasoning. The researchers evaluated the student responses to these misconception scenarios using a guided rubric. This activity was designed to help students move from remembering and understanding to higher-order tasks of analyzing and evaluating mathematical properties in solving algebraic problems. This presentation will describe the use of correct and incorrect student work as a tool for explicitly addressing and eliminating students' mathematical misconceptions and how it increased students' precalculus readiness. (Received September 17, 2013)

1096-VE-2339 **D. Christopher Stephens*** (chris.stephens@mtsu.edu), **Sarah K. Bleiler** and **Wesley A. Baxter**. *A Mathematician's Foray into the Common Core State Standards (for Mathematical Practice): A Question of Interpretation?* Preliminary report.

In early 2013, I joined a team of mathematics educators to provide professional development to sixty local elementary school math teachers. One of my initial responsibilities was to conduct pre-observations of instruction in our participants' classrooms. We were to use an 8-item behavioral checklist, which, unbeknownst to me, corresponded to the eight Common Core State Standards for Mathematical Practice (SMP). After my first observation, I learned of the connection to the SMP and decided to explore them further. For me, an eight-item list of Mathematical Practices was unstructured and unwieldy; thus I resolved to organize and structure the SMP so that I could better internalize them. This act of structuring, though, led me to realize I did not fully understand the SMP, and our group conversations suggested varying interpretations of the SMP across our project team and teacher participants (e.g., how to distinguish between SMP #7/#8). We decided to collect data from mathematicians, mathematics educators, and K-12 teachers to better understand stakeholders' interpretations of the SMP, and to ultimately guide the design of our professional development. We share the results of those investigations and discuss implications for policy and practice. (Received September 17, 2013)

1096-VE-2374 **Kacey M Diemert*** (diemert@math.montana.edu). *Putting Professional Development into Practice: How Teachers Implement and Share their Knowledge of the Common Core State Standards for Mathematics with Peers – The Research Process and Early Results.* Preliminary report.

The Common Core State Standards for Mathematics (CCSSM) outline content expectations for K-12 students, but do not mandate use of specific curriculum or teaching methods. While such flexibility is embraced in the culture of American schooling, it leaves states to cope independently with the responsibility of successful implementation. Some states face unique challenges due to rural isolation, variation in support structures, and limited resources, calling for a differentiated and school-based approach to CCSS implementation.

Teacher cohorts in Montana are charged with leading school-based change as part of a three-year PD project focused on designing a systemic and sustainable approach to implementing the CCSSM. This study takes place at a critical juncture in the implementation process, when teacher participants transition from receiving professional development to sharing their practice with peers. This qualitative case study explores how the cohorts implement the CCSSM, the professional knowledge they identify as most valuable to support teaching with the CCSSM, and the factors influencing implementation. Data sources include focus group interviews, observations of school-based meetings, and cohort strategic plans. The research process and early results will be presented. (Received September 17, 2013)

1096-VE-2455 **Hashim A Saber*** (hashim.saber@ung.edu), 3820 Mundy Mill Rd, Oakwood, GA 30542. *Flipped model utilizing Effective Learner-Centered and Performance-Based Instruction.*

This presentation involves the development of a flipped model utilizing learner-centered, inquiry-intensive, and Performance-Based strategies. The proposed framework for the flipped model is a blend of selected ingredients of two well-known research-based frameworks, Understanding By Design (UBD) and Dimensions Of Learning (DOL), and some additional ingredients. We have developed a flexible unit/lesson design template that incorporated the proposed framework which is translated to our three-stage instructional model that includes to Engage and Explore (Access prior knowledge, stimulate thinking, and set the stage and trigger students' interest and Provides time to think about the concepts and skills to be learned with minimal teacher guidance), Explain and Expand (Guide students to construct meaning from their exploration and Apply new conceptual understanding to a unique situation and expands understanding of the concept) , and the third stage is Employ (Applies and transfers students' understandings to meaningful use situations to solve problems, and produce products or performances as outlined in Engage). Evaluation is done within the stages. Examples of lesson plans in science, mathematics and other disciplines will be given. (Received September 17, 2013)

1096-VE-2489 **Kathleen D. Lopez***, UL Department of Mathematics, P. O. Box 41010, Lafayette, LA 70504, and **Patricia Beaulieu** (pwb0555@louisiana.edu) and **Peter A. Sheppard** (psheppard@louisiana.edu). *Louisiana Mathematics Masters in the Middle.* Preliminary report.

Louisiana Mathematics Masters in the Middle 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 17, 2013)

1096-VE-2534 **Thorsten Scheiner*** (thorsten.scheiner@googlemail.com). *Mathematical Concept Construction through the Interaction of Reflective and Structural Abstraction.* Preliminary report.

The purpose of the theoretical work presented here is twofold: On the one hand, this work intends to advance our understanding of the interrelationships between reflective and structural abstraction, two cognitive processes underlying different ways of concept construction. Embedded in a broader theoretical framework in the context of knowledge formation considered on a fine-grained level of knowledge structures, the question is addressed whether these two cognitive processes are exclusively distinct. On the other hand, this work gives new insights into two theoretical perspectives concerning knowledge formation, namely the knowledge-in-structures and the knowledge-in-pieces perspective. In this presentation, it is assumed that these perspectives are rather complementary than mutually exclusive. (Received September 17, 2013)

1096-VE-2572 **Marianna Bonanome***, mbonanome@citytech.cuny.edu, and **Margaret H. Dean**. *Introducing Interesting Groups in an Introductory Abstract Algebra Course.*

Most introductory abstract algebra courses at the undergraduate level will spend a fair amount of time on group theory. Isomorphism theorems, theory of abelian groups, and theory of finite groups may be covered in some detail. The common nonabelian groups provided as examples include dihedral symmetry groups, permutation groups and matrix groups. It can be challenging to provide further interesting infinite groups that can be explored and understood in some detail. In this talk we propose several interesting groups, such as Thompson's group F, the Lamplighter group L_2, and self-similar groups, which can be made accessible to an undergraduate audience. We also discuss some of the difficulties that can arise when introducing them at the undergraduate level. (Received September 17, 2013)

1096-VE-2579 **Donna L. Beers*** (donna.beers@simmons.edu). *Using Think-Alouds in an Undergraduate Mathematics Course for Preservice Elementary School Teachers.* Preliminary report.

One of the important service roles of my department is the preparation of preservice elementary school teachers to teach elementary school mathematics. In fall 2013, I taught the first course, in a two-course sequence for preservice teachers, which covers number systems, number operations, patterns, relations, functions, and problem-solving. Two of the stated goals of the course were to (1) strengthen students' ability to give mathematical explanations which are clear, complete, and of appropriate rigor, and (2) develop students' capacity to appraise mathematical explanations, both their own and those of their classmates. This presentation will focus on how small group think-alouds were used to advance the above goals. This talk will describe problems which were used for the think-alouds, how the interviews were structured and recorded, and the rubric students utilized for appraising their own explanations and those of team-mates. It will end with an assessment of how well the think-aloud approach worked and plans for future improvements. (Received September 17, 2013)

1096-VE-2594 **Hong Yuan*** (hyuan@bmcc.cuny.edu), 199 Chambers St, New York, NY 10007, and **Jean W Richard** (jrichard@bmcc.cuny.edu), 199 Chambers St, New York, NY 10007. *The Evolution of Teaching Mathematical Modeling in China.*

The evolution of teaching mathematical modeling takes place for social, scientific, and economic reasons. In this presentation, we will consider this evolution in three historical periods. The earliest evidence of mathematical modeling ideas in China appears in the book JiuZhang SuanShu, or also known as Nine Chapters on the Mathematical Art (Nine Chapters) in the 1st century CE. This was used as a textbook until Western science was introduced into the Far East around 1600 AD. Between 1958 and 1962, a group of Chinese mathematicians emphasized the teaching of mathematical modeling to workers and farmers, and popularized mathematical modeling thinking to high school students by solving real world problems. Since 1990, high school and college mathematical modeling competitions have been organized in Beijing and Shanghai, and the Mathematics National Curriculum included mathematical modeling as a standard for mathematical practice in 2000. Examples of teaching mathematical modeling in the three periods will be discussed. (Received September 17, 2013)

1096-VE-2666 **Brittany D. Smith*** (bds2x@mtmail.mtsu.edu), **Elaine Bouldin Tenpenny**, **Jennifer Yantz**, **Thomas Cheatham**, **Donald Nelson**, **Ginger Holmes Rowell** and **Chris Stephens**. *Precalculus Preparation Program for Mathematically Underprepared STEM Majors: A Tool for Increasing Retention.*

Universities across the nation are working to increase retention rates for STEM majors. At Middle Tennessee State University (MTSU) precalculus is an early obstacle for many students who major in a STEM discipline. Therefore, our project recruits students whose first college mathematics course is precalculus. MTSU's Mathematics as a FirstSTEP to Success in STEM project is a 5-year, $2 million NSF-funded exploration of interventions that address mathematics deficiencies in STEM majors. MTSU first-time, full-time freshman STEM majors who are at-risk based on mathematics ACT test scores between 19 and 23, inclusive, participate in an intensive two-year program that includes a mathematics precalculus preparation program, two years of concentrated academic support, and an intense, introductory research experience at the end of their freshman year. This presentation focuses on the success of the precalculus preparation program, which uses four different instructional strategies to increase students' readiness for precalculus: individualized computer assisted instruction, direct teacher-led instruction, group-based hands-on activities, and peer-led learning. (Received September 17, 2013)

1096-VE-2673 **Paul E. Seeburger*** (pseeburger@monroecc.edu), Monroe Community College, 1000 E. Henrietta Rd., Rochester, NY 14623. *Making Calculus Come Alive with Dynamic Visualization Tools.*

A tour of several Java applets developed by the presenter to help students visualize calculus. Although the presenter has developed over 100 applets for various calculus textbooks, all of the applets demonstrated in this presentation can be found on the presenter's 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, 3D graphs of functions of two variables, parametric curves and surfaces, etc. In addition to his work on applets for visualizing single variable calculus, the presenter is also the PI of an NSF funded project that focuses on helping students visualize multivariable calculus. See http://web.monroecc.edu/calcNSF. (Received September 17, 2013)

1096-VE-2691 **Suzanne Keilson*** (skeilson@loyola.edu), 4501 north charles street, baltimore, MD 21210. *What to include in a numeracy course.*

This paper outlines the curriculum that was developed for a numeracy course that was taught in a Master's of Liberal Studies program of Loyola University Maryland. This curriculum covers topics in both "quantitative literacy" and "quantitative aesthetics" as described in the text. It is hoped that such a broad curriculum, as well as the use of educational technology such as video clips from YouTube can be easily adapted for use in K-12 and undergraduate education generally as well as for those interested in adult education. (Received September 18, 2013)

1096-VE-2692 **Erin R Moss*** (erin.moss@millersville.edu). *Math meets drama: Introducing constructivist pedagogy to prospective elementary teachers.*

In this talk, I share an activity I use at the beginning of each semester in a mathematics course for preservice elementary teachers, and I discuss how I use it to introduce constructivist pedagogy that builds on student thinking. I select student volunteers to read and act out a "play" that dramatizes an actual situation that occurred in an elementary classroom. The play presents a Kindergarten student's interactions with his teacher as he encounters the square root concept. At certain key moments in the dialogue, I stop the play and ask all of my students to write down how they would respond to the boy if they were his teacher. Afterwards, we compare and contrast the ways that my students envisioned responding to the boy with the ways that his teacher chose to interact with him. My preservice teachers typically write down responses that discourage the boy from continuing his mathematical explorations, yet the boy's actual teacher engages with him in a way that promotes his curiosity and helps him make profound yet age-appropriate discoveries about the square root concept. This activity highlights the differences between the didactic mathematics pedagogy that most of my students experienced in grades K-12 with a pedagogy that is responsive to students' thinking. (Received September 18, 2013)

General Session on Mathematics and Technology

1096-VF-80 **Ping Wang*** (pxw10@psu.edu), Department of Mathematics, Penn State University, 200 University Drive, Schuylkill Haven, PA 17972. *Technology in Mathematics Education.* Preliminary report.

In this work, we create and integrate interactive/animated computer graphics and programs and electronic texts into mathematics teaching in classrooms. Students will be able to learn mathematics more easily and more effectively because they can make better connection between abstract concepts/symbols and relevant pictures; between seemingly boring replication of procedures and visual interactive process; between theoretical terminologies/rules and clear animations in color. (Received July 15, 2013)

1096-VF-214 **Mimi Tsuruga*** (tsuruga@math.tu-berlin.de), TU Berlin, Str. 17.Juni 136, MA 2-2, 10623 Berlin, Germany, and **Frank H. Lutz**. *Constructing Complicated Spheres.*

As a result of great advancements in technology, we now face the problem that the amount of data we are able to collect far exceeds what we can process. One direction researchers are taking to solve this issue is to simplify the data using topological methods. These simplification algorithms, unfortunately, can only be heuristic at best since the foundations on which they are built — such as finding an optimum discrete Morse vector or recognizing spheres — are NP hard.

To test those heuristics, we have produced triangulations of a space from smooth topology for which such simplification has been shown to be difficult. These simplicial complexes are explicit representations of the Akbulut–Kirby spheres, an infinite series of 4-spheres based on a handlebody construction via finitely presented groups, which were once thought to be exotic. (Received September 12, 2013)

1096-VF-1080 **Victor Kostyuk***, 2000 Bering Dr., Suite 300, Houston, TX 77057, and **Nathaniel Rounds** and **Paulette N. Willis**. *Computer assisted instruction in mathematics.*

Currently computers and tablets are being used to individualize a students' learning experience. The first technology for doing that, however, has been in use for centuries – namely, the textbook. In the past 50 years, the evolution of adaptive learning has accelerated rapidly, and its development has been marked by both successes and failures. We briefly outline recent progress in individualizing math learning, introduce the emerging science of multimedia instruction, and outline the challenges in creating effective digital tools for learning mathematics.
(Received September 12, 2013)

1096-VF-1120 **Pamela E Harris*** (pamela.harris@usma.edu), United States Military Academy, Department of Mathematical Sciences, 46 Swift Road, West Point, NY 10966.
Strengthening Communication Skills Through Student Created Homework Videos.

The wide availability of online tutorial videos has revolutionized the way students learn mathematics. In this talk, we will summarize finding from a project were students created their own homework videos by using the screen-capture recording capabilities of an iPad. The aims of these videos were twofold. First, through the creation of homework videos students conveyed technical information; this helped strengthen their communication skills. A second objective was the development of an online library of videos that students could study from in preparation for homework and exams. We will address some findings of this project and provide ideas for ways instructors can implement such projects in their classrooms. (Received September 13, 2013)

1096-VF-1573 **Tamara Eyster*** (teyster@kaplan.edu). *The Game Makers Toolshed - Tools for Creating Serious Games.*

While a wide variety of ready-to-play games can be found online, seldom is a game a perfect fit for the concept the instructor would like students to master. When a good fit is not readily available, there are tools instructors can use to create their own digital games. Different tools can be used at different stages of the design process from concept to completion. We will look at some of the tools through the spectrum of price and required programming skills, starting with QuizGame Master, eToys, and Scratch to GameMaker, Unity and Flash.
(Received September 16, 2013)

1096-VF-1615 **Lea L Rosenberry*** (lrosenberry@kaplan.edu), 2426 Broad Avenue, Altoona, PA 16601.
Screencasting on the iPad to Enhance Student Engagement.

Screencasts enable instructors to quickly and easily provide a student-centered and engaging learning experience. Instead of trying to find existing video online, instructors can create a screencast which aligns with specific lessons or answers student's questions. In addition to effective instruction, the screencast also allows for a more personal connection between the instructor and student(s). Several popular screencasting options are available for the computer, but we will focus on Showme for the iPad. Showme Interactive Whiteboard is an app that turns your

iPad into a personal interactive whiteboard. Showme allows you to record your own tutorials and share them online or via email with students. Showme works well for students and instructors making instructional videos easy to create and share. (Received September 16, 2013)

1096-VF-1909 **Jeffrey C. Kallenbach*** (jkallenb@sienaheights.edu), 1247 E. Siena Heights Drive, ADRIAN, MI 492211592, and **Timothy H Husband**. *Modern Technology In The Classroom - Calculators and Accessories for the applied math experiment.*

One question that persists in the modern pedagogy is, how/how much should we use handheld calculators or other such devices in the classroom. We have found a nice contained application for the NSpire CAS and ancillaries, in the undergraduate course in differential equations. We present a demonstration on the collection, analysis, and presentation of simple experimental data in a single class session using these tools. (Received September 16, 2013)

1096-VF-2022 **Sofokli Garo*** (sofokligaro@gmail.com), Rr. Currilave, Durres, Albania. *Handheld calculators and mathematics thinking.*

The objective of this study was to examine the effect of hand-held calculators on mathematical achievement of Albanian high school students. In May 2012, 484 tenth-grade students from five large high schools in the city of Durres (Albania) participated in the study. The data collection instrument consisted of the same mathematics achievement test. Test items involved simple computations, which did not necessitate the use of calculators. The sample included two groups. The first group consisted of 290 students. These were not calculator users, and therefore did not use calculators on the test. The second group consisted of 194 students. Since these were calculator users, they were allowed to use calculators on the test. Regarding the overall achievement, results indicate that the group of calculator users, scored significantly higher than the group of non-calculator students. The results of t-test procedures also showed that the first group scored significantly higher than the second group in the three cognitive domains of understanding, namely, in the knowing, applying and reasoning domain. Lastly, presence of calculators on the test seemed to encourage students to use algebra for solving word problems. (Received September 17, 2013)

1096-VF-2508 **Charles Bergeron*** (chbergeron@gmail.com), Albany College of Pharmacy, and Health Sciences, 106 New Scotland Avenue, Albany, NY. *A program of weekly activities for learning Calculus using the computer algebra system Maxima.* Preliminary report.

I teach a single-semester Calculus course that covers most topics typically found in a year-long sequence, but with less depth, to first year pre-Pharmacy and pre-Medical students.

During the first week of classes, we download and install the open-source computer algebra system Maxima onto student laptops. One hour per week, I teach students the commands and syntax to execute 5 skills: define a function, plot a function, solve an equation, differentiate a function and integrate a function. With these skills, students complete lab activities, such as (1) plotting secant and tangent lines towards a better understanding of the limit definition of the derivative, (2) evaluating a definite integral that gives the area between curves, (3) finding and interpreting critical numbers as local extrema, and (4) solving optimization word problems.

Much of the course focus is on interpreting graphs and understanding the geometric significance of the derivative and integral. Maxima gives students a way to learn these ideas without being bogged down by weak precalculus skills. A lab manual is being written that can be used as a supplementary text for a calculus course. (Received September 17, 2013)

General Session on the Modeling and Applications of Mathematics

1096-VG-44 **Sanjeev Kumar*** (sanjeevibs@yahoo.co.in), Dept. of mathematics, Dr. B.R. Ambedkar University, IBS, Khandari Campus, Agra, UP 282002, India. *The Tumors Cell Density and Immune Response System: A Mathematical Model.*

Complex mathematical models of cancerous growths have been developed, especially on solid tumors, in which growth primarily comes from cellular proliferation during the last 20 years. Consider a procedure for cancer therapy which consists of interaction between immune response (immune cells) and tumor cells without any specific drug. The cytotoxic T lymphocyte (CTL) and tumor necrosis factor (TNF) cause of the immune response. This process is modeled as a system of tumor cell density (TCD) and tumor necrosis factor (TNF). The purpose of this work is to establish a rigorous mathematical analysis of the model and to explore the density/concentration of tumor cell and immune response (TNF). The result suggests that although TCD capable to growth of tumor but the immune response is block to direct tumor growth. The model assumes that only two factors need be considered for such predictions: net growth rate and infiltrative ability. (Received June 13, 2013)

1096-VG-93 **Longhua Zhao*** (lxz315@case.edu) and **Maria-Carme Calderer**. *Phase transitions in gels with two-phase model.* Preliminary report.

Due to the physical complexity of gels and lack of fully understanding, numerous challenges arise in developing accurate mathematical models of dynamical gel behavior. We build a regularized two-phase model for gels to handle the ill-posedness for the problem. To demonstrate the property of the problem, we consider the gel in one dimension and analytically explore the periodic solution for 1D problem. With special initial conditions, there exist traveling wave solutions. These results can be applied to investigate the volume phase transition in gels. (Received July 24, 2013)

1096-VG-168 **Brian J Winkel*** (brianwinkel@hvc.rr.com), 26 Broadway, Cornwall, NY. *Modeling Scenarios and Strategies in Differential Equations Course.* Preliminary report.

We present and discuss modeling strategies used to motivate the study of mathematics, especially in the area of differential equations. We offer accessible modeling scenarios for students in many disciplines and demonstrate how the activities draw students to the mathematics and develop a "need to know" mindset. This work is the basis of an on-going effort to offer an alternative approach to teaching differential equations through modeling and technology, in SIMIODE - Systemic Initiative for Modeling Investigations and Opportunities with Differential Equations at www.simiode.org. (Received August 12, 2013)

1096-VG-359 **Michele L Joyner*** (joynerm@etsu.edu), **Chelsea R Ross**, **Colton Watts** and **Thomas C Jones**. *A Stochastic Simulation Model for Anelosimus studiosus during Prey Capture.*

In this talk we derive a stochastic differential equation model to simulate the movement of a social/subsocial spider species, Anelosimus studiosus, during prey capture using experimental data collected in a structured environment. In a subsocial species, females and their maturing offspring share a web and cooperate in web maintenance and prey capture. Furthermore, observations indicate these colonies change their positioning throughout the day, clustered during certain times of the day while spaced out at other times. One key question was whether or not the spiders spaced out "optimally" to cooperate in prey capture. We first show the derivation of the model using experimental data to determine key parameters within the model. We then discuss possible spatial configurations for maximal prey capture using the model to simulate a spider path at feeding time. (Received August 30, 2013)

1096-VG-374 **Pawel Dlotko*** (dlotko@sas.upenn.edu), Department of Mathematics, University of Pennsylvania, Philadelphia, PA. *Algebraic topology in computational electromagnetism.*

For many decades Maxwell's equations in the form of PDE's have been used to describe electromagnetic phenomena in electric circuits. In the '80 a so called Discrete Geometric Approach (DGA) to Maxwell's laws has been introduced. The DGA builds a discrete counterparts of Maxwell's laws in a given mesh which consist of conducting and insulating sub-meshes. However, when the topology of conductors is nontrivial, so called cuts are needed to make the discrete laws well defined. For many years the engineering community has struggle to provide a good definition and algorithm to compute cuts. In this talk we will give an idea of DGA and define the cuts as a representatives of a first cohomology group basis of insulator. We will show that this is a correct definition of cuts, in a sense that only such a cohomological information makes the DGA consistent. We will also provide an efficient algorithms to compute cohomology generators. At the end we will present results of our computations for a industrial size meshes. (Received August 30, 2013)

1096-VG-433 **Dorjsuren Badamdorj*** (dbadamdo@tnstate.edu), Department Of Mathematical Sciences, Tennessee State University, 3500 John A Merit Blvd, Nashville, TN 37221. *Spatial Distribution of Calcium-Gated Chloride Channels in Olfactory Cilia.*

To determine the spatial distribution of the chloride channels, we recorded from single cilia as calcium was allowed to diffuse down the length of the cilium and activate the channels. A mathematical model consisting of partial differential equations is developed for this experiment and used to estimate the spatial distribution of the chloride channels. On average, the channels were concentrated in a narrow band centered at a distance of 29% of the ciliary length, measured from the base of the cilium. This matches the location of the CNG channels determined previously. This non-uniform distribution of transduction proteins is consistent with similar findings in other cilia. (Received September 03, 2013)

1096-VG-829 **William P. Fox*** (wpfox@nps.edu), Department of Defense Analysis, NPS, Monterey, CA 93943. *Mathematical Modeling for Empowering Decision Making.*

We teach a three course sequence in mathematical modeling that includes deterministic models, stochastic models, and decision theory models. Our students are weak mathematically but they are able to solve and interpret very sophisticated problems because of the power of the computer. We are limited to Excel since our students all have access to Excel both during class and will have access to Excel at work after graduation. Within the time constraints, I will present several examples and quickly describe the modeling and the use of the computer to solve problems, aide in sensitivity, and help interpret the results. (Received September 10, 2013)

1096-VG-928 **Kimberly A Carstens*** (kimberlycarstens@mail.adelphi.edu), 42 North Maryland Ave., Port Washington, NY 11050, and **Salvatore Giunta** (sgiunta@adelphi.edu), 152 bismark ave, valley stream, NY 11581. *Correlation and Regression Between Habits and Dental Hygiene.* Preliminary report.

We determined if habits formed in early childhood effect a child's dental health in an approximate time span of three years. We distributed a survey to second graders and fourth graders, ranging in age from six to nine. The purpose of this analysis was to assist parents and caregivers in improving dental well being. We concluded, utilizing correlation an regression models, Anova testing, the chi square test, and statistical analysis involving the t distribution, that habits not directly related to a child's dental health do eventually have an impact. (Received September 11, 2013)

1096-VG-942 **Ghan S Bhatt*** (gbhatt@tnstate.edu), 3500 John A. Merritt Blvd, Nashville, TN 37209, and **Ross Beckley**, **Cametria Weatherspoon**, **Michael Alexander**, **Anthony Johnson** and **Marissa Chandler**. *Modeling epidemics using differential equations.* Preliminary report.

The well known SIR models have been around for many years. Under some suitable assumptions, the models provide information about when does the epidemic occur and when it doesn't. The models can incorporate the birth, death, and immunization and analyze the outcome mathematically. In this project we studied several SIR models including birth, death and immunization. We also studied the bifurcation analysis associated with the disease free and epidemic equilibrium. (Received September 11, 2013)

1096-VG-944 **Junkoo Park*** (jun-koo.park@houghton.edu), One Willard Ave., Houghton, NY 14744. *Elastic Network Model Extensions for Predicting Protein Residue-level Fluctuation.* Preliminary report.

Proteins are an important class of biomolecules, and they are fundamental research subjects of life sciences. While a protein folds to a unique structure, it makes dynamic fluctuations. These movements may correspond to certain functions and provide valuable insights for drug design. Therefore, studying the structural fluctuation is essential in protein modeling. Accurate predictions on its structural fluctuations may provide great insights into how the dynamics of the structure relate to their functions. The structural fluctuations can be analyzed theoretically for a given structure. Elastic Network Model (ENM) has been proposed recently and proved to be reasonably accurate. In this paper, we propose a refined Gaussian Network Model (GNM) which is based on atomic interaction potential, and compare the refined GNM with other elastic network models. The refined GNM has been shown to perform well for predicting residue-level structural fluctuations. The goal of this study is to extend the ENM and apply it to protein structures and analyze the results, and further improve our predictions. (Received September 11, 2013)

1096-VG-1218 **Suzanne Robertson*** (srobertson7@vcu.edu) and **Kevin Caillouet**. *The role of avian stage-structure in the transmission of West Nile virus.*

West Nile virus (WNV) has remained an annual public health concern in the United States since its introduction in 1999, yet the ecological triggers leading to seasonal outbreaks are not well understood. While the annual occurrence of WNV in humans has been associated with the end of the avian nesting season, no specific mechanism has been demonstrated to describe if and how the end of nesting leads to amplification of the virus. As birds within the first couple of weeks of hatching (nestlings) are extremely vulnerable to mosquitoes, they may be preferred over older birds, receiving a disproportionately high number of mosquito bites. While total avian population size increases throughout the season, nestling abundance declines at the end of the brooding season. This reduction in nestlings may concentrate mosquitoes on the last few remaining nestlings, significantly increasing the vector-host contact ratio for this stage. We develop a stage-structured differential equation model for WNV incorporating vector preference for specific host life stages, and investigate the impact of host selectivity as well as vector and host abundance on the timing of enzootic and epizootic WNV activity. (Received September 13, 2013)

1096-VG-1227 **Tyler Skorczewski*** (tskorc@math.utah.edu). *Multi-bond models of platelet adhesion.*
The initial response to blood vessel injury is formation of a platelet aggregate to seal off the damage to the vascular wall. To form the aggregate, platelets adhere to the vascular wall and cohere to one another. Both of these processes involve the interplay of multiple types of receptor-ligand bonds with different force-dependent binding kinetics. The local fluid dynamics affects the bond dynamics by exerting shear stresses on the platelets. We present a mesoscale stochastic binding model based on recent experimental data about platelet receptor-ligand interactions and incorporate it into an immersed-boundary-based platelet aggregation model. Multiple bond types and activation of platelets in response to binding are parts of the model. Simulation results illustrate that the model can capture the stop-start motion of a platelet along the vessel wall as well as the activation-dependent firm adhesion that has been observed experimentally. (Received September 13, 2013)

1096-VG-1283 **Kiersten Utsey*** (kmutsey@gmail.com), **Samuel Estes**, **Erick Kalobwe**, **Heather Finotti** and **Xiaopeng Zhao**. *Mathematical Modeling of Fetal Electrocardiograms.*
Some of the most common and fatal birth defects are related to the heart. In adults, possible heart conditions are often identified through the use of an electrocardiogram (ECG). However, due to the presence of other signals and noise in the recording, fetal electrocardiography has not yet proven effective in diagnosing these defects. This paper develops a mathematical model of three-dimensional heart vector trajectories, which we use to generate synthetic maternal and fetal ECG signals. This dipole vector model simulates the electrical activity of the heart as a single time-varying vector originating at the center of the body. We use a system of ordinary differential equations and two sets of parameters to simulate maternal and fetal cardiac activity. Various physiological factors, including heart rate variability and baseline wander, are also simulated. These cardiac dipole vectors are then projected onto three dimensional unit vectors to simulate fetal electrocardiogram (fECG) data collection. White noise and power line noise are added to the projections. Using this model, we have built a database of realistic, synthetic fECG signals using different parameter values and noise levels. This database can be used in effectiveness testing of fetal signal extraction algorithms. (Received September 14, 2013)

1096-VG-1297 **Michael A. Karls*** (mkarls@bsu.edu), Department of Mathematical Sciences, Ball State University, Muncie, IN 47306. *Verifying the Hanging Chain Model.*
The wave equation with variable tension is a classic partial differential equation that can be used to describe the horizontal displacements of a vertical hanging chain with one end fixed and the other end free to move. Using a web camera and Tracker software to record displacement data from a vibrating hanging chain, we verify a modified version of the wave equation with variable tension that accounts for damping. (Received September 14, 2013)

1096-VG-1496 **Romarie Morales***, MCMSC Physical Science A – Wing, Room 524, PO Box 871904, Tempe, AZ 85287-1904, and **Jay Taylor**. *Best policy implementation when there is parameter uncertainty; a Bayesian and adaptive control approach.* Preliminary report.
We focus on improving the current methodology for estimating transmission parameters by applying a Bayesian statistical framework with a probabilistic model of disease transmission and generalizing this formulation to any disease. This method takes into account the intrinsic stochasticity of disease transmission and provides more robust parameter estimates.We then use adaptive control techniques with the updated parameters in order to obtain the best policies to minimize the cost infection. Increasing estimation accuracy through the adoption of the Bayesian updating framework will equip policymakers with better tools for mitigating the effects of an epidemic. (Received September 16, 2013)

1096-VG-1506 **Shigeru Masuda*** (hj9s-msd@asahi-net.or.jp), 56-5-202 Yoshida-Izumidono-chou, Sakyo-ku, Kyoto, 6068301, Japan. *Kepler Problems mathematically contributed to Quantum Mechanics.*
Kepler (1571-1630) 1634 proposes laws on the motions of planets in reserving many analytical open problems : how to determine true anomaly from mean anomaly by calculus and how to approximate it by the expression. Since then, many mathematicians have devoted themselves from the mathematical viewpoint. At first, Lagrange(1736-1813) 1771 defines the orthodoxy Kepler problem and calculates with the trigonometric series. Laplace(1749-1827) studies many sorts of celestial mechanics, including the problem of secular perturbation (secular variation). Poisson(1781-1840) 1808 discusses the problem of secular perturbation after Laplace, of the

Keplerian third law problem in depth and deduces the today's approximate method by third order. Gauss(1777-1863) 1818 calculates the perturbation of a planet in accordance with the Keplerian second law. Bessel(1784-1846) 1820-21 cites Gauss and contributes mathematically. On the other hand, the new paradigms of Kepler problem are constructed like relative Kepler motion. Boltzmann(1844-1906) 1872 constructs thermodynamics equations based on the concepts of molecular collision, entropy and probability, and Schrödinger(1887-1961) 1926 proposes the modern quantum equations by the analogy of Kepler motion. (Received September 17, 2013)

1096-VG-1658 **Felicia Maria G Magpantay*** (felicigm@umich.edu). *Numerical analysis of delay equations.* Preliminary report.

As with ordinary differential equations (ODEs), delay differential equations (DDEs) generally have to be solved numerically. The standard approach to do this is to look at existing ODE methods and extend them to accommodate the delay terms. However there is a lot to consider when making this extension, especially when the delay is state-dependent. In this talk we will consider some of the issues that arise when numerically integrating delay equations. We will also look at some applications to state-dependent delay equations such as an age-structured population model consisting of the McKendrick partial differential equation and a threshold condition. (Received September 16, 2013)

1096-VG-1721 **Jacquelyn L. Rische*** (jrische@math.uci.edu) and **Natalia L. Komarova**. *Regularization of languages by learners: a mathematical framework.*

E.L. Newport and colleagues have demonstrated that both children and adults have some ability to process inconsistent linguistic input and "improve" it by making it more consistent. We create a learning algorithm of the reinforcement-learning type, which exhibits patterns reported by Hudson Kam and Newport (2009) and suggests a way to explain them. In order to capture the differences between children's and adults' learning patterns, we need to introduce a certain asymmetry in the learning algorithm. Namely, we have to assume that the reaction of the learners differs depending on whether or not the source's input coincides with the learner's internal hypothesis. We interpret this result in the context of a different reaction of children and adults to positive and negative evidence. We propose that a possible mechanism that contributes to the children's ability to regularize an inconsistent input is related to their heightened sensitivity to positive evidence rather than the (implicit) negative evidence. In our model, regularization comes naturally as a consequence of a stronger reaction of the children to evidence supporting their preferred hypothesis. The adults' ability to adequately process implicit negative evidence prevents them from regularizing the inconsistent input. (Received September 16, 2013)

1096-VG-1728 **Mohamed Allali*** (allali@chapman.edu). *Gradient and Laplacian-Type Edge Detection.*

Image manipulation is attractive and leads to creative and meaningful exploration of the image's content, and appreciation of the mathematics built into the process on many levels. One of the most studied problems in the image analysis area is edge detection as enormous information is contained in image edges. If one defines an edge as an abrupt gray-level change, then the derivative, or gradient, is a natural basis for an edge detector. In this talk, I will show how to use the gradient and the Laplacian approaches as the basis for practical image edge detectors and how it can be incorporated as a solid project into many mathematics courses. (Received September 16, 2013)

1096-VG-1743 **Mark A. Krines*** (mark-krines@uiowa.edu). *A Probabilistic Exploration of Consistency in Positional Voting Procedures.* Preliminary report.

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". In this talk, I will discuss a statistical model which determines probabilities regarding the inconsistency of positional voting procedures when candidates are removed from consideration. (Received September 16, 2013)

1096-VG-1794 **Danilo R. Diedrichs*** (danilo.diedrichs@wheaton.edu), Wheaton College, Mathematics and Computer Science Department, 501 College Avenue, Wheaton, IL 60187, and **Paul A. Isihara** and **Doeke D. Buursma**. *The Schedule Effect: can recurrent peak infections be reduced without vaccines, quarantines or school closings?*

Using a basic, two transmission level seasonal SIR model, we introduce mathematical evidence for the schedule effect which asserts that major recurring peak infections can be significantly reduced by modification of the traditional school calendar. The schedule effect is observed first in simulated time histories of the infectious population. Analysis of the phase plane explains the relationship between the maximum recurring infection peaks and the period of an oscillating transmission function. The response may exhibit period-doubling and chaos induced at certain periods, leading to increased peaks. We show how to take these effects into consideration to design an optimum school schedule. (Received September 16, 2013)

1096-VG-1795 **Jason M Graham*** (jason.graham@scranton.edu), 204 Monroe Ave, Scranton, PA 18510, and **Bruce P Ayati**, **Sarah A Holstein** and **James A Martin**. *The Dynamics of Bone Turnover.*

Bone, like all other organs of the body, constantly and continuously undergoes change. The process responsible for most of this change in a mature skeleton is known as bone remodeling. Bone remodeling involves dynamic interactions of two distinct classes of specialized cells, and is activated and regulated via complex biochemical signaling. Moreover, irregular bone remodeling is associated with several prominent diseases. In this talk we briefly describe the cell signaling network that underlies bone remodeling, focusing on some recent work toward developing a mathematical and computational framework for investigating the dynamics of bone turnover. (Received September 16, 2013)

1096-VG-1888 **Lochana Siriwardena*** (lochana@siu.edu). *Stochastic Models for Population Dynamics.* Preliminary report.

I discuss various properties of stochastic models for population dynamics. I construct and analyze some stochastic delay models and non-delay models, produced using the infinitesimal mean and variance given by birth and death rate functions. Delay models are a result of allowing birth and death rates to depend on the population size at a prior time which would take the maturity time in to account. Drift terms are set up in the form of the logistic growth and delayed logistic growth functions. I discuss the existence and uniqueness of the global solution, boundedness of the moments of the solution and non-negativeness of the solution and, for some models, the boundedness of the path. Uniqueness is guaranteed using a regularization of the non-Lipschitz diffusion terms. That also causes the solutions to be persistent. Some models are discussed as Itô diffusions with absorbing barriers. Hitting times are also discussed for non-delay models and a new idea is presented for analyzing the hitting times of a class of discrete delay models. (Received September 16, 2013)

1096-VG-1921 **Zeynep Akcay*** (za25@njit.edu), Departent of Mathematical Sciences, New Jersey Institute of Technology, University Heights, Newark, NJ 07102-1982, and **Amitabha Bose** and **Farzan Nadim**. *Effects of Synaptic Plasticity on Phase and Period Locking of a Network of Two Oscillatory Neurons.*

We study the effects of synaptic plasticity on the determination of firing period and relative phases in a network of two oscillatory neurons coupled with reciprocal inhibition. We combine the phase response curves of the neurons with the short-term synaptic plasticity properties of the synapses to define Poincaré maps for the activity of an oscillatory network. Fixed points of these maps correspond to the phase locked modes of the network. These maps allow us to analyze the dependence of the resulting network activity on the properties of network components. Using a combination of analysis and simulations, we show how various parameters of the model affect the existence and stability of phase-locked solutions. We find conditions on the synaptic plasticity profiles and the phase response curves of the neurons for the network to be able to maintain a constant firing period, while varying the phase of locking between the neurons or vice versa. A generalization to cobwebbing for two-dimensional maps is also discussed. (Received September 16, 2013)

1096-VG-1962 **Bryan Alexander Dawkins*** (bdawkins@uco.edu) and **Sean Michael Laverty** (slaverty@uco.edu). *A Mathematical Model of Laser-Initiated Immunotherapy of Cancer.*

We will present a mathematical model composed of a system of ordinary differential equations describing the treatment dynamics of cancer cell populations with exponential growth. The model will include laser-initiated cancer destruction by means of several classes of immune cells. We will show successful treatment and the conditions under which this may occur. Also, we will describe conditions under which failed treatment may occur. To expand the model, treatment of cancer cell populations with non-exponential growth will be discussed as well. We will show that the ultimate success of laser immunotherapy of cancer is highly related to immunoadjuvants represented by parameters of our model. (Received September 16, 2013)

1096-VG-1974 **Whitney Leeann Forbes*** (forbesw@goldmail.etsu.edu) and **Michele Joyner**. *A Physiologically-Based Pharmacokinetic Model for Ertapenem.*

Ertapenem is a carbapenem used to treat a wide range of bacterial infections. We developed a physiologically-based pharmacokinetic model for the distribution of ertapenem within the body. What sets ertapenem apart from other carbapenems is its longer half-life which implies it need only be administered once daily. In the model, parameters such as human body weight, organ volumes, and blood flow rates of particular tissues are used to examine the absorption, distribution, metabolism, and excretion of ertapenem. The blood concentrations we found were then compared to experimental data. In the future, this model could be used as a basis for understanding how differing health conditions alter the concentration of ertapenem in the body. This could identify potential situations where the dosage should be adjusted. (Received September 16, 2013)

1096-VG-1980 **Keith Wojciechowski** and **Kelsey Linnell***, klinnell@bowdoin.edu. *A Mathematical Model for a Self-Expanding Hemostatic Bandage.*

In this talk we discuss the use of a nonlinear partial differential equation (PDE) to model the absorption and swelling behaviors of a bandage made with Self Expanding Hemostatic Polymers (SEHPs). The PDE may be viewed as the result of applying some simplifying assumptions to a nonlinear Volterra partial integrodifferential equation used in the modeling of biopolymers. We applied this PDE to model a square bandage and prescribed boundary conditions appropriate for the case where a wound saturates the center of the bandage but flow is not permitted along any of the exterior edges. Behavior of the model is analyzed through analytic techniques and compared to known viscoelastic properties of polymer diffusion. We confirm that the simplified model captures the desired behavior of non-Fickian diffusion thus indicating that it may be applied successfully to modeling SEHP bandages. Numerical solutions for a assortment of diffusion coefficients are then presented and discussed in terms of this expected behavior. (Received September 17, 2013)

1096-VG-2143 **James Brian Hall*** (j9hall@math.ucsd.edu), Department of Mathematics, University of California, San Diego (UCSD), 9500 Gilman Drive #0112, San Diego, CA 92093-0112. *Automated Estimation of Wound Size.*

When monitoring the healing of a wound, one of the key measurements is the area, or size, of the wound. Standard practices of wound size estimation are either extremely inaccurate or labor intensive. In this talk, I present work done in collaboration with researchers at the UCSD medical center for developing an automated wound size estimator based on photographs of wounds. I will show how, using techniques from machine vision, it is possible to estimate the size of a wound with minimal user input, and compare this approach to the standard methods of wound size estimation. (Received September 17, 2013)

1096-VG-2218 **Brandon J Wilson*** (pandamathium@gmail.com), 361 N 300 W Apt 207, Provo, UT 84601. *Time Optimal Control in General Relativity.* Preliminary report.

Optimal control is the process of trying to steer or control a system from one state to a more preferred state while minimizing a cost functional. Current research on systems modeled on the principles of Einstein's theory of General Relativity are focused on finding geodesics in certain classes of Finsler metrics, rather than optimal control proper. This is effective in giving optimality conditions, but does not combine as well with other control theoretic concerns such as stability and control of noisy systems. Jose Natario and Pedro Henriques recast these problems in the language of differential geometric control theory with a particular emphasis on fuel optimal control. We give an overview and consider time-optimal control which has a number of distinct possible definitions in the relativistic setting. In particular we focus on conditions when the same trajectory is the optimal solution for differing time functions. (Received September 17, 2013)

1096-VG-2231 **Najat Ziyadi*** (najat.ziyadi@morgan.edu), Department of Mathematics, Morgan State University, 1700 East Cold Spring Lane, Baltimore, MD 21251, and **Avner Friedman** (afriedman@math.osu.edu), Department of Mathematics, The Ohio State University, 231 West 18th Avenue, Columbus, OH 43210. *A mathematical model of human papillomavirus with application to cervical cancer in African women.*

Cancer is an emerging public health problem in Africa, and cervical cancer, one of the most diagnosed cancers, is the leading cause of cancer death in African women. Epidemiological studies have shown that the association of human papillomavirus (HPV) with cervical cancer is very strong. We use a mathematical model to assess the epidemiological consequences of human papillomavirus on cervical cancer prevalence in Africa. Furthermore, we use the next generation method to compute the basic reproduction number, R0, of the mathematical model. We obtain that R0<1 implies disease extinction whereas R0>1 implies disease persistence. (Received September 17, 2013)

1096-VG-2308 **Benjamin Allen**, **Yulia Dementieva**, **Ruben Medeiros**, **Christopher Paoletti** and **Christine Sample*** (samplec@emmanuel.edu), Emmanuel College, 400 The Fenway, Boston, MA 02115. *Asymmetric population structure alters the molecular clock.* Preliminary report.

Neutral substitution occurs when mutations that offer no advantage or disadvantage become fixed in a population by random chance. Under simple models of evolution, the rate of neutral substitution at the population level equals the rate of neutral mutation at the individual level, regardless of the population size. These results support the "molecular clock" hypothesis that evolutionary time can be measured by counting genetic substitutions. We use a graph-theoretic model to investigate the effects of spatial population structure on the molecular clock rate C, defined as the expected number of neutral mutations arising within a single generation that ultimately go to fixation. We obtain the novel result that asymmetric population structures can alter the molecular clock rate. In particular, if birth rates are constant over all individual sites, the molecular clock rate is less than or equal to that of a well-mixed population, with equality if and only if death rates are also constant over sites. On the other hand, if there are no constraints on birth or death rates, the molecular clock rate can be greater than the baseline (well-mixed population) value. Thus the constancy of the molecular clock is not as general as previously thought. (Received September 17, 2013)

1096-VG-2368 **Muna Khaled Khaleel Abu Alhalawa*** (munahalaweh@hotmail.com), San Antonio, TX 78212, and **Henrique Olivera** and **Saber Elaydi**. *Stability and bifurcation of a three dimensional Ricker model.*

In this talk we focus on the Ricker competition model of three species. We present an analysis of the stability and local bifurcation of the fixed points. We will be mainly dealing with the symmetric case. (Received September 17, 2013)

1096-VG-2398 **Dan Carroll** (dcarroll1@smcm.edu), **Nora Stack** (nhstack@smcm.edu) and **Caroline VanBlargan*** (cgvanblargan@smcm.edu). *Maps and Mirrors.* Preliminary report.

We investigate extensions of mirror design problems inspired by classical map projections. The map maker's problem is to choose which geographic/geometric data her map will reflect and which it will distort. Given that the simultaneous preservation of angles and areas is not possible, for instance, we explore new, so-called "quasiconformal mirrors" whose distorting tendencies can be controlled. (Received September 17, 2013)

1096-VG-2413 **Minjeong Kim***, min.kim@ucdenver.edu, University of Colorado Denver, and **Jan Mandel**, jan.mandel@ucdenver.edu, University of Colorado Denver. *Traveling wave solutions of reaction-diffusion fire model with fuel depletion.*

We present a highly simplified PDE-based wildland fire model as a nonlinear reaction diffusion equation, coupled with a fuel depletion equation without diffusion. We observe that a physical behavior, such as a traveling combustion wave, can be achieved by such simple model, and identify the coefficients of the PDEs from field measurements. We reduce a traveling wave solution of the PDE system to a system of ODEs by the phase-space method. However, because of the fuel depletion, we obtain a more difficult shooting problem in a 3D phase space instead of a standard 2D argument, such as, for example, for the Komogorov-Fisher equation. We study traveling wave solutions by a geometric analysis in the phase space using the invariant manifold approach. We prove that a traveling wave cannot exist under certain conditions, which yields inequalities relating the coefficients of the PDEs and the traveling wave speed. This research was partially supported by NSF grant EGS-0835579. (Received September 17, 2013)

1096-VG-2537 **Laura R. Gonzalez-Ramirez*** (rgonz@bu.edu), 111 Cummington Mall, Boston, MA 02215, and **Omar Ahmed**, **Sydney S. Cash**, **C. Eugene Wayne** and **Mark A. Kramer**. *Descriptive analysis and modeling of wave propagation during epileptic seizures.*

Epilepsy – the condition of recurrent, unprovoked seizures – manifests in brain voltage activity with characteristic spatio-temporal patterns. One type of pattern observed during a seizure is a traveling wave. To characterize these waves, we consider high-density local field potential data recorded *in vivo* from human cortex during a seizure. Using a mean-field approach we develop a mathematical model consistent with the observed neuronal population activity and determine analytically the parameter configurations that support traveling wave solutions. We then employ the clinically observed voltage activity to constrain the model parameters, and propose latent biophysical mechanisms that contribute to the observed traveling waves. We describe the biological implications of such regime. (Received September 17, 2013)

1096-VG-2573 **Ariel Cintron-Arias*** (cintronarias@etsu.edu), Department of Mathematics and Statistics, Box 70663, East Tennessee State University, Johnson City, TN 37614. *Extensions to the Daley-Kendall model.* Preliminary report.

A model for two interacting species is formulated and analyzed. Conditions for the existence of a Hopf bifurcation are given. Longitudinal observations are used to estimate model parameters. A sensitivity analysis is carried out for two dynamical scenarios: when the system supports a co-existence stable equilibrium and when periodic solutions exist. In both scenarios the most influential parameters, in one of the state variables, are explored. (Received September 17, 2013)

1096-VG-2575 **Larry Wayne Lewis*** (llewis61@ivytech.edu) and **Rebecca Patterson** (becky.patterson@louisville.edu). *A Mathematical Modeling Approach to Informing Student Retention Programming.*

Mathematical predictive modeling using data mining techniques of student data can be an effective tool for addressing issues of enrollment management, institutional fit, and persistence to graduation. First year retention of the Graduation Rate Survey (GRS) cohorts (2006, 2007, 2008, and 2009) was examined. Variables from applications, financial aid, demographic data, and the Cooperative Institutional Research Program (CIRP) Freshman Survey were used in a binary logistic regression equation to identify factors which accurately predicted students' first year retention. Our efforts are to demonstrate an intentional, data-driven approach to support and strengthen pre-existing programs or mechanisms relating to student retention. (Received September 17, 2013)

1096-VG-2583 **Alyssa Miller** and **Haley A Yaple*** (hyaple@carthage.edu). *A new application of the two-group competition model.* Preliminary report.

A differential equation model for two-group competition has been used to describe diverse systems, including language death, the decline of religion, and ferromagnetism. A new sociological application of this model will be presented, along with the real-life data that is used to find the best-fit model. (Received September 17, 2013)

1096-VG-2632 **Rebecca E. Gasper***, rebecca-gasper@uiowa.edu. *Action Potentials in Peripheral Auditory Nervous System: A Novel PDE Distribution Model.* Preliminary report.

Long have Speech and Hearing Pathologists analyzed clinical reaction speeds by constructing histograms (graphs with reaction times sorted into time interval 'boxes'). Their goal is to experimentally model reaction time of a neuron as a function of stimulus strength. Since a popular model for single-node action potential magnitude is known (Hodgkin-Huxley), we can use numerical methods to create an entire probability distribution of firing times. Mathematically, we transition from a deterministic nonlinear ODE to an advection-diffusion PDE which represents distribution of all the states of ODE variables over time. Using steady-state assumptions or more complicated assumptions such as stochasticity, we show preliminary results to the question "When will a neuron fire and how does the distribution of firing times depend on parameters?" (Received September 17, 2013)

1096-VG-2674 **Sean M Laverty*** (slaverty@uco.edu) and **Bryan Dawkins**. *Anti-tumor immune dynamics: using ODEs to model a novel cancer therapy.* Preliminary report.

We use a system of differential equations to describe interactions between cancer cell populations and components of the immune system in a host undergoing treatment by a promising anti-tumor treatment. In particular, we focus on an anticancer laser immunotherapy that helps train the body's own immune system to detect and destroy cancer cells, including metastases. Using the model we explore the dynamics and post-therapy outcomes of a variety of treatment programs, and identify features of both the program and the host immune system that facilitate cancer clearance. To analyze the model with numerical methods, we plan to use Latin Hypercube Sampling to help explore a potentially large, and somewhat uncertain, parameter space in this high-dimensional dynamical model. When possible, we plan to make frequent comparisons between model output and experimental data provided by our collaborators. Anti-tumor antibodies are thought to be important in cancer clearance, but their role in this treatment is not as well understood dynamically or mechanistically. We hope to use the model to elucidate the dynamics and role of antibodies in cancer clearance. (Received September 17, 2013)

1096-VG-2688 **Colin Pawlowski*** (colin.pawlowski@yale.edu), **Matthew McDermott**, **Emma Hartman**, **Ryo Kimura**, **Jessica Ginepro** and **Dylan Shepardson**. *Novel Properties of Deterministic and Stochastic SIR Models.*

Compartmental differential equation models are among the most established disease models in mathematical epidemiology. In particular, the SIR model, first formulated by Kermack and McKendrick, serves as the theoretical foundation for many current disease models. We investigate the asymptotic properties of several stochastic variations of the basic, deterministic SIR model. We perform sensitivity analysis on input parameters such as the rate of infection and the basic reproductive number (the expected number of secondary infections per infected individual). For a compartmental stochastic implementation of the SIR model restricted to certain parameter ranges, we find distributions of the final epidemic size to be normal, with standard deviations given by the basic reproductive number and the total population size. (Received September 18, 2013)

1096-VG-2698 **Kamal Kevin Barley*** (kindleye@asu.edu), 2430 S. Mill Ave. Apt. 207, Tempe, AZ 85282. *Risk factors in the spread of Visceral Leishmaniasis in two highly endemic but ecologically different regions.* Preliminary report.

Visceral Leishmaniasis (VL) has been on the rise in the two highest prevalent regions: India and Sudan. Similar hosts and parasite characteristics are observed in these two countries but variance in estimates of epidemiological quantities are different. WHO aims to eliminate the disease by 2020, however, various unknown risk factors and undetected high incidence of asymptomatic cases may pose a barrier in achieving the target for the two countries. A vector-host epidemic model, accounting for asymptomatic and treated individuals, is developed to compare and contrast the mechanisms that contribute to the level of risk posed for VL for the two nations. The analysis of the model is uniquely determined by the basic reproductive number, $\mathcal{R}_0$, measuring the transmission potential of the Leishmania parasite.Various public health department reports and data sets, including data from the literature, were thoroughly reviewed to obtain estimates of demographical and epidemiological parameters related to the two populations. Using these estimates we conducted uncertainty and sensitivity analyses to assess the most influential risk factors that contribute to the high endemic levels of VL observed in Sudan and India. (Received September 18, 2013)

1096-VG-2704 **Jason Karl Davis*** (jdavis8@ucmerced.edu), 5200 N Lake Rd, School of Natural Sciences, Merced, CA 95343, and **Suzanne S Sindi** (ssindi@ucmerced.edu), 5200 N. Lake Rd, School of Natural Sciences, Merced, CA 95343. *An Enzymatic Model of Prion Aggregate Dynamics.*

Prion proteins are responsible for a variety of diseases in mammals such as Creutzfeldt-Jakob disease in humans and mad-cow diease in cattle. According to the prion hypothesis, misfolded versions of a protein appear and form prion aggregates, complexes of multiple misfolded proteins ranging in size from tens to hundreds of proteins. The prion state is infectious and spreads to healthy proteins by conversion of the healthy confirmation to the misfolded state (which increases the size of the aggregate). Prion aggregates also increase in number by fragmentation, thus increasing the number of templates which act to convert healthy proteins.

The dynamics of prion aggregates have been investigated with a number of mathematical models. Most mathematical models assume that the fragmentation rate is proportional to the size of the aggregate; we present yeast data to demonstrate the inadequacy of this assumption, then extend the model to include the effects of an enzymatic limitation. Experiments have shown that changing a separate protein's expression levels has measurable effects on the aggregate size distribution, suggesting its role as a molecular chaperone in the fragmentation process. We perform general analyses of our more complete model, then compare it with experimental data.
(Received September 18, 2013)

1096-VG-2727 **Youssef M Dib*** (dib@ulm.edu), 700 Univ. Ave, Monroe, LA 71209, and **Anton Dudko**. *Relationship between hitch-hiking and Mathematics.*

A statistical study is performed from data collected by hitch-hikers after visiting N points of attractions. This study prove that the expected time for getting from point A to a point B lies under a bell shape curve when outliers are eliminated. After deeper investigation through stochastic process theory, a mathematical relationship between number of attractions points (N) and time needed to visit them (t) was established. (Received September 18, 2013)

1096-VG-2763 **Erin Bodine** and **Anne Yust*** (ayust@bsc.edu), Birmingham, AL. *New Paradigms for Collaborative Undergraduate Research in Biomathematics.*

Mathematics faculty from Hendrix College, Rhodes College, Sewanee College, and Birmingham-Southern College received a grant from the Associated Colleges of the South (ACS) to test pilot a new collaborative (intercollegiate) summer research experience for undergraduates (REU). The pilot program allowed students from different colleges to collaborate on mathematics research projects while remaining at their respective colleges making use of technology like Google Hangouts to enable rich communication between the student researchers and between the faculty advisors. Profs. Bodine (Rhodes) and Yust (Birmingham-Southern) co-advised the biomathematics research project. We will discuss the benefits and pitfalls of this long-distance method of collaboration, and share the lessons we learned about directing undergraduate biomathematics research projects. (Received September 19, 2013)

General Session on Probability and Statistics

1096-VH-47 **Thomas W. Hair*** (twhair@fgcu.edu). *Benford's Law of First Digits and the Mass of Exoplanets.*

Benford's Law refers to the frequency distribution of first digits in many natural and human-constructed sources of data. In this distribution, the number 1 occurs as the leading digit approximately 30% of the time, while larger numbers occur in that position with decreasing frequency. This distribution of first digits is the same as the widths of gridlines on a logarithmic scale and its results have been applied to a wide variety of data sets. From pulsar rotation rates to accounting fraud detection, this distribution tends to be most accurate when values within a data set are distributed across multiple orders of magnitude. Exoplanet mass data from the Exoplanet Orbit Database is analyzed for goodness-of-fit with the predicted distribution of first digits implied by Benford's Law. The surprisingly close match between the two suggests a limited predictive ability for the mass distribution of exoplanets. (Received June 15, 2013)

1096-VH-211 **Taylor C Corcoran***, taylorc3@email.arizona.edu, and **Jirapat Samranvedhya**.
Benford Behavior of Dependent Random Variables. Preliminary report.

Many mathematical, man-made, and natural systems exhibit a leading-digit bias, where a first digit (base 10) of 1 occurs not 11% of the time as one would expect if all digits were equally likely but rather 30%. This digit bias is known as Benford's Law and arises in diverse fields, ranging from computer science to forensic accounting. Benford's Law is vital to the analysis of large datasets and is an important means of detecting data tampering and fraud. Analyzing which datasets adhere to Benford's Law and how quickly Benford behavior sets in are the two most important problems in the field.

Inspired by natural processes such as particle decay, we study the dependent random variables that emerge from models of decomposition of conserved quantities. We prove that in many instances the distribution of lengths of the resulting pieces converges to Benford behavior as the number of divisions grow. The main difficulty is that the resulting random variables are dependent, which we handle by a careful analysis of the dependencies and tools from Fourier analysis to obtain quantified convergence rates. We also apply these techniques to the determinant expansion of $n \times n$ matrices with entries drawn from 'nice' distributions. (Received August 19, 2013)

1096-VH-428 **Adam F Childers*** (childers@roanoke.edu), 221 College Lane, Salem, VA 24153.
Sensitivity in Experimental Design. Preliminary report.

We will investigate experiment designs for continuous non-linear models with repeated samples. Maximizing the determinant of the Fisher information matrix for an apriori parameter estimate provides information about a D-Optimal design (or a near V-Optimal design) but will often times not provide robustness due to sensitivity with respect to the initial parameter estimate. By defining the apriori parameter estimate to be a random variable we will consider the distribution of the determinant of the FIM to identify where and when in time to sample in order to identify robust designs. (Received September 03, 2013)

1096-VH-511 **Nicholas Taylor*** (tayman2037@hotmail.com) and **Narayan Thapa** (narayan.thapa@minotstateu.edu). *A Markov Chain Approach to Baseball Run Forecasting.*

A baseball general manager's role is to field a competitive team of twenty-five players while operating under defined financial constraints. In recent years, advanced baseball statistical research and analysis, spurred by Billy Beane's Moneyball A's, has driven many teams to install their own statistical divisions within their front offices to better assess players' potential contributions, thus minimizing the cost/production ratio of these players. In this presentation, we consider Markov Chains as a forecaster of a player's offensive potential and their use in predicting a team's run scoring capacity. (Received September 05, 2013)

1096-VH-589 **Marina Skyers*** (marinaskyers@gmail.com), SUNY Maritime College, 6 Pennyfield Avenue, Throggs Neck, NY 10465. *A Random Walk Theme for an Undergraduate Research Project.*

This talk will present an idea for undergraduate research related to the random walk. The prerequisites for this research project are topics covered in basic statistics, introduction to proofs and discrete mathematics courses. (Received September 09, 2013)

1096-VH-697 **Pradip R Aryal*** (pradip@nmsu.edu), New Mexico State University, Department of Mathematical Science, P.O. Box 30001 Department 3MB, Las Cruces, NM 88003. *Transition density of a Brownian motion in upper-half space under Brachistochrone-type metrics.*

"I will derive some expressions for the transition density of a Brownian motion in upper-half spaces under Brachistochrone-type metrics. In one regime, 0<alpha< 2 these variable curvature metrics sit between Euclidean Brownian motion and hyperbolic Brownian motion. In this case the process has a killing time which can be expressed in terms of Bessel processes of negative dimension. In the other regime 2<alpha they behave as more extreme analogs of hyperbolic Brownian motion which never exit the domain." (Received September 09, 2013)

1096-VH-1026 **Allison Davidson*** (atdavid@purdue.edu), **Hosam Mahmoud** and **Mark Daniel Ward**. *Characterization of Tenable Pólya Urns.*

We characterize tenable Pólya urn schemes via a decomposition of their replacement matrices into small submatrices with certain conditions on the determinants. The characterization also involves an interplay between the submatrices and the initial conditions, as well as certain divisibility conditions. (Received September 12, 2013)

1096-VH-1390 **George Mytalas*** (mytalas@aueb.gr), 236 86Str Brooklyn, New York, NY 11209. *An M/G/1 Queue System with Feedback, Disasters and Repairs with Vacation.*

We study a queueing system with batch Poisson arrivals and Bernoulli feedback subject to disasters. Server when remains empty takes vacation of arbitrary distribution, while we consider two models of vacation policies, single and multiple. Also after completion of the service customer can immediately join the tail of the queue as a feedback customer for receiving another service with probability r. Otherwise the customer may depart forever from the system with probability 1-r. The server, whenever is busy serving customers, is subject to disasters which occur according to a Poisson process, independent of all other processes in the system. When a disaster occurs the system is cleared of all customers and the server initiates a repair period. During the repair period arriving batches of customers accumulate in the queue without receiving service. When the system becomes empty as a result of the server serving the last customer waiting in line, the server takes vacations single or multiple, dependent of the model. We analyze this system using the supplementary variables technique and we obtain the probability generating function of the stationary queue length distribution and the Laplace transform of the busy period's distribution. (Received September 15, 2013)

1096-VH-1417 **Ram C Kafle*** (rckafle@mail.usf.edu), Department of Mathematics and Statistics, University of South Florida, Tampa, FL 33620, **Netra Khanal** (nkhanal@ut.edu), The University of Tampa, Tampa, FL 33606, and **Chris P Tsokos** (ctsokos@usf.edu), University of South Florida, Tampa, FL 33620. *Bayesian Age-stratified Joinpoint Regression Model: An Application to Lung and Brain Cancer Mortality.*

Joinpoint regression model identifies significant changes in the trends of the incidence, mortality, and survival of a specific disease in a given population. The purpose of the present study is to develop an age-stratified Bayesian joinpoint regression model to describe mortality or incidence trends assuming that the observed counts are probabilistically characterized by the Poisson distribution. The proposed model is based on Bayesian model selection criteria with the smallest number of joinpoints that are sufficient to explain the Annual Percentage Change (APC). The prior probability distributions are chosen in such a way that they are automatically derived from the model index contained in the model space. The proposed model and methodology estimates the age-adjusted mortality or incidence rates in different epidemiological studies to compare the trends by accounting the confounding effects of age. In developing the subject methods, we use the cancer mortality counts of adult lung and bronchus cancer, and brain and other Central Nervous System (CNS) cancer patients obtained from the Surveillance Epidemiology and End Results (SEER) data base of the National Cancer Institute (NCI). (Received September 15, 2013)

1096-VH-1560 **Jebessa B Mijena*** (jebessa.mijena@gcsu.edu), 231 W. Hancock St., CBX 017, Milledgeville, GA 31061, and **Erkan Nane**. *Strong Analytic Solution of Fractional Cauchy Problems.*

Fractional derivatives can be used to model time delays in a diffusion process, in which a cloud of particles spreads in a different manner than traditional diffusion and have appeared as an essential tool for the study of dynamics of various complex stochastic processes arising in anomalous diffusion in physics, finance, hydrology, and cell biology. When the order of the fractional derivative is distributed over the unit interval, it is useful for modeling a mixture of delay sources. In some special cases distributed order derivative can be used to model ultra-slow diffusion. In particular, we develop the strong analytic solutions of distributed order fractional Cauchy problems. (Received September 16, 2013)

1096-VH-1568 **Prateek Bhakta**, **Sarah Miracle*** (sarah.miracle@gatech.edu), **Dana Randall** and **Amanda Pascoe Streib**. *Mixing Times of Markov Chains for Self-Organizing Lists and Biased Permutations.*

We study the mixing time of a Markov chain $\mathcal{M}$ on permutations that performs nearest neighbor transpositions in the non-uniform setting, a problem arising in the context of self-organizing lists. We are given "positively biased" probabilities $\{p_{i,j} \geq 1/2\}$ for all $i < j$ and let $p_{j,i} = 1 - p_{i,j}$. In each step, the chain $\mathcal{M}$ chooses two adjacent elements k, and ℓ and exchanges their positions with probability $p_{\ell,k}$. We define two general classes and give the first proofs that the chain is rapidly mixing for both. In the first case we are given constants $r_1, \ldots r_{n-1}$ with $1/2 \leq r_i \leq 1$ for all i and we set $p_{i,j} = r_i$ for all $i < j$. In the second we are given a binary tree with n leaves labeled $1, \ldots n$ and constants $q_1, \ldots q_{n-1}$ associated with all of the internal vertices, and we let $p_{i,j} = q_{i \wedge j}$ for all $i < j$. Our bounds rely on bijections between permutations, *inversion tables* and *asymmetric simple exclusion processes* that allow us to express moves of the chain in the context of these other combinatorial families. We also demonstrate that the chain is not always rapidly mixing. This proof relies on a reduction to biased lattice paths in $\mathbb{Z}^2$. (Received September 16, 2013)

1096-VH-1985 **Y Park*** (park@ncbi.nlm.nih.gov) and **J Spouge**. *Markov Random Walk and Its application to Sequence Alignment Statistics.*

Computational tools for biological sequence alignment are indispensable to modern molecular biology. Nowadays, the functional, structural, and evolutionary relationships of a novel protein or nucleic acid sequence are often inferred by finding similar sequences of known function in a database. Here, we investigate sequence alignment statistics. We model the alignment of random sequences heuristically with Markov additive processes. Its optimal alignment score is explained by ascending ladder scores of the Markov random walk process. In sequence alignment, the heuristic suggests a numerical acceleration scheme for simulating an important asymptotic parameter for the sequence alignment statistics. (Received September 17, 2013)

1096-VH-2042 **Raid M Al-Aqtash*** (raid.al-aqtash@uc.edu), Cincinnati, OH 45219. *The Gumbel-Weibull Distribution: Properties and Applications.*

A member of the family of T-X distributions arising from the logit function, namely the Gumbel-Weibull distribution is studied. A detailed discussion of regions of unimodality and bimodality is given. The method of maximum likelihood is proposed for estimating the parameters and a simulation study is conducted to assess the performance of the method. To illustrate the application of the distribution, several data sets are used to fit the distribution and compared to the fits from other existing distributions. (Received September 17, 2013)

1096-VH-2139 **Keshav P. Pokhrel*** (kpokhrel@mercyhurst.edu), 501 East 38th Street, Erie, PA 16546, and **Chris P. Tsokos**. *Functional Forecasting Models for Brain Tumor Mortality Rates.*

Incidence and mortality rates are considered as a guideline for planning public health strategies and allocating the resources. We present forecasting models using functional data analysis techniques. Nonparametric smoothing methods are used to mitigate the existing randomness in the observed data. Our primary goal is to find a robust forecasting model for the mortality rates of the brain and central nervous system tumors in the United States. We also present the disparity of brain cancer mortality rates among the age groups together with the rate of change of mortality rates. In addition, we apply *principal differential analysis* to measure the noisy features of the data in a single curve and the variations of the data are also measured across the curves. The data were obtained from the Surveillance, Epidemiology and End Results (SEER) program of the United States. (Received September 17, 2013)

1096-VH-2179 **Huybrechts Frazier Bindele*** (hbindele@southalabama.edu), 411 University Blvd. North, ILB 325, Mobile, AL 36688-0002. *Signed Rank with Responses Missing at Random.*

This paper is concerned with the study of the signed-rank estimator of the regression coefficients under the assumption that some responses are missing at random in the regression model. Strong consistency and asymptotic normality of the proposed estimator are established under mild conditions. To demonstrate the performance of the signed-rank estimator, a simulation study is conducted under different settings of errors' distributions, and shows that the proposed estimator is more efficient than the least squares estimator whenever the error distribution is heavy tailed or contaminated. When the errors follow a normal distribution, the simulation experiment shows that the signed-rank estimator is more efficient than its least squares counterpart whenever a large proportion of the responses are missing. (Received September 17, 2013)

1096-VH-2199 **Melody Denhere*** (mdenhere@umw.edu), Department of Mathematics, University of Mary Washington, 1301 College Ave, Fredericksburg, VA 22401, and **Nedret Billor**. *Robust Penalized Functional Logistic Regression.*

With the advancement in technology, there has been an increased interest to study functional data. The collection and analysis of dense data has resulted in the development of statistical techniques that deal with data where functional predictors are collected for (often a few) subjects. In this work, we propose a robust estimation method for the functional logistic regression model. This approach is based on penalization to ensure that the estimated parameter function is a smooth function as well as incorporating a process for down-weighting outlying functional predictors. The proposed robust penalized method is a Mallows type estimate with a Huber-type loss function being used to down-weight the high leverage observations. Results from a simulation study and a real world example are also discussed to illustrate the performance of the proposed method. (Received September 17, 2013)

1096-VH-2289 **Ahmad Alzaghal*** (alzag1am@cmich.edu), 619 S. Pine St., Mount Pleasant, MI 48858. *On the Properties of Exponentiated Weibull-Exponential Distribution.*

The mode of the exponentiated Weibull-exponential distribution (EWED) is studied. For some parameter values, the EWED can be unimodal or bimodal and the region of the bimodality is obtained. The method of maximum likelihood is used to estimate the EWED parameters and a simulation study is carried out to assess its performance. For discriminating between EWED and the Weibull distribution, a simulation study is conducted to evaluate the performance of three tests. Applications to real world data are also provided. (Received September 17, 2013)

1096-VH-2435 **Howard Troughton*** (htroughton@babson.edu), **George Recck** and **William Rybolt**. *Let's Make a (New) Deal: Variations of the Monty Hall Problem.*

A familiar problem in the teaching of probability is the classic Monty Hall problem. A contestant is presented with three doors with a major prize behind one of the doors and booby prizes behind the other two. After the contestant chooses a door, the host opens one of the other doors revealing a booby prize and then offers the contestant the option of sticking with the original choice or switching to the remaining door. Contrary to most people's intuition, the contestant's odds of winning improve from 33% to 67% by switching choices! Most students, and even some mathematicians, have a difficult time accepting the validity of this result.

This talk will present the solution using payoff tables instead of Bayes Theorem, and will also present some variants to the classic problem, including cases with more than three doors, cases with multiple major prizes, and cases with multiple prizes of different values. (Received September 17, 2013)

1096-VH-2524 **Salam M. Khan*** (kmmahbub@gmail.com), Department of Mathematics, Alabama A&M University, 4900 Meridian Street, Normal, AL 35762. *Approximations of the Generalized Exponential Distribution.*

The generalized exponential distribution is a two parameter distribution. This distribution is becoming increasingly useful in many branches of science specially related to semi-infinite reservoir model. 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 approximated the generalized exponential distribution by using different techniques and suggested the best approximation. We also derived the standard normal approximation of generalized exponential distribution. 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 17, 2013)

1096-VH-2667 **Ibrahim Abdelrazeq*** (iabde083@uottawa.ca), B-24 Rene-Marengere, Gatineau, Quebec j8y 1m9, Canada, and **Gail Ivanoff** and **Rafal KuliK**. *Model Checking: Levy-Driven Ornstein-Uhlenbeck Processes.*

Lévy-Driven Ornstein-Uhlenbeck (or CAR(1)) processes were introduced by Bandorff-Nielsoen and Shephard (2001) as a model for stochastic volatility. Pham-Din-Tuan (1977) and Brockwell et al. (2007) developed a general formula to recover the unobserved driving process from the continuously observed CAR(1) process. When the CAR(1) process is observed at discrete times $0,\ h,\ 2h, \cdots\ [T/h]h$ the driving process must be approximated. Approximated increments of the driving process are used to test the assumption that the process is Lévy-driven. Asymptotic behavior of the test statistic is centered at high sampling frequencies. Performance of the test is illustrated through simulation. (Received September 17, 2013)

1096-VH-2679 **Paul R. Coe*** (coepaul@dom.edu), Department of Mathematics, Dominican Univeristy, 7900 W. Division St., River Forest, IL 60305. *Should anyone ever "Pass" on Family Feud?* Preliminary report.

On the TV show Family Feud, two families of four contestants compete to name the most common responses to personal questions. In each round, one person from each family tries to guess the most common answer to a question posed to 100 people. Whichever contestant has the more frequent response is given the opportunity to 'Play' or 'Pass'. If the contestant chooses to 'Play', the members of his or her family take turns attempting to name the rest of the answers given until either all of the answers are named or three incorrect answers are named. If all of the answers are named, they win the round. Otherwise, the other family has the opportunity to steal the round by naming one more answer. If it is correct, they win the round; otherwise, the original family wins the round. If the winning contestant chooses to 'Pass', then the roles are reversed. In practice, no one ever says 'Pass'. Their team also seldom names all of the other correct answers before three incorrect ones. In my presentation, I will describe how the game show is played. I will present data on the number of answers in each round and the performance of the actual contestants. I will analyze these results in an effort to find situations where it may be more advantageous to 'Pass' than to 'Play' Family Feud. (Received September 17, 2013)

1096-VH-2681 **Ann E Moskol*** (amoskol@ric.edu), 2 Longmeadow Rd, Lincoln, RI 02865, Afghanistan. *Student involvement with the central limit theorem through software using MIT's Imagination Toolbox.* Preliminary report.

Students often have difficulty understanding the central limit theorem. Using MIT's Imagination Toolbox, I have written a program that allows students to select the population and sample size, and the proportion of flowers in the population. My program models this process by having a graphic object (in this case, a Brown bear) randomly move through a field of flowers and grass, counting the number of flowers and grass with which s/he collides until the total collisions equals the sample size. I will demonstrate my program and describe how I used it in my introductory statistics course. (Received September 17, 2013)

1096-VH-2720 **Yasin Asar*** (yasar@konya.edu.tr), Yeni Meram Caddesi, Ahmet Kelesoglu, Egitim Fakultesi, A1 Blok No:105, Meram, 42090 Konya, Turkey, and **Asir Genc** (agenc@selcuk.edu.tr), Selcuk Universitesi , Alaeddin Keykubat, Yerleskesi, Fen Fakultesi, Istatistik Bolumu, 42030 Konya, Turkey. *On Liu-type estimators for the logistic regression.*

Logistic regression is a widely used statistical method. In most of the situations of logistic regression, independent variables are collinear. It is known that multicollinearity affects the variance of maximum likelihood estimator (MLE). This paper introduces new shrinkage estimators for logistic regression. A Monte Carlo study is used to show the goodness of the proposed estimators over MLE in the sense of mean squared error (MSE). (Received September 18, 2013)

1096-VH-2738 **Martial Longla*** (mlongla@olemiss.edu), University of Mississippi, Department of Mathematics, 308 Hume Hall, Oxford, MS 38677. *Mixing coefficients and mixtures of distributions.*

We will present a review of some conditions on copulas that guarantee mixing properties such as ρ, ϕ, ψ among others. Knowing that mixtures of distributions are very popular in modeling, it is important to answer the question on mixing coefficients for models that involve them. They allow estimation of functions of the random variables or inference on model parameters. We will present some situations when mixtures of copulas generate various types of mixing structures. (Received September 20, 2013)

General Session on Research in Algebra and Topology

1096-VJ-735 **Sara Jensen*** (jensen@math.wisc.edu). *On the Character Degree Simplicial Complex of a Finite Solvable Group.* Preliminary report.

The common divisor simplicial complex of a set of integers X has as its simplices all subsets $Y \subseteq X$ satisfying $\gcd(Y) > 1$. Every finite group G has an associated set of integers, called character degrees, denoted by $\mathrm{cd}(G)$. The common divisor simplicial complex associated to the set of integers $\mathrm{cd}(G)$ is called the character degree simplicial complex of the group G.

In classical character theory, one learns that the structure of the group G largely influences the values that may occur in the set $\mathrm{cd}(G)$. This talk will focus on a sort of converse; that is, given a simplicial complex X, can this simplicial complex occur as the character degree simplicial complex of a finite group G? (Received September 09, 2013)

1096-VJ-836 **Nathaniel J Schwartz*** (nschwartz2@washcoll.edu), 300 Washington Avenue, Chestertown, MD 21620. *On the k-involutions of $O(n,k)$ when k has characteristic 2.* Preliminary report.

The characterization and classification of k-involutions of algebraic groups enables one to determine much of the structure of the related symmetric k-varieties. The characterization of k-involutions of connected, reductive algebraic groups over algebraically closed fields of characteristic not 2 is complete, and recently the k-involutions of $SL(n,k)$ and $SO(2n+1,k)$ over perfect fields of characteristic not 2 has been completely classified. Here we proceed with a similar theme, but k is any field of characteristic 2, and we focus on $O(n,k)$. (Received September 10, 2013)

1096-VJ-860 **Bradley M Wagner*** (bradley_wagner@baylor.edu) and **Manfred Dugas**. *Finitary Incidence Algebras and the Idealization of $I(P)$.* Preliminary report.

Let P be an arbitrary partially ordered set and $I(P)$ its incidence space. Then $F(P)$ is the finitary incidence algebra and $I(P)$ is a bimodule over it. Consequently we can form $D(P) = FI(P) \oplus I(P)$ the idealization of $I(P)$. In this paper we will study the automorphisms of $FI(P)$ and $D(P)$. (Received September 10, 2013)

1096-VJ-976 **Jung Wook Lim*** (jwlim@knu.ac.kr), Department of Mathematics, Kyungpook National University, 80 Daehakro, Bukgu, Daegu, 702-701, South Korea. *Noetherian properties on generalized power series rings.*

Let $D \subseteq E$ be an extension of commutative rings with identity, I be a nonzero proper ideal of D, $(\Gamma, \leq)$ be a strictly totally ordered monoid such that $0 \leq \alpha$ for all $\alpha \in \Gamma$ and $\Gamma^* = \Gamma \setminus \{0\}$. Let $D + [\![E^{\Gamma^*,\leq}]\!] = \{f \in [\![E^{\Gamma,\leq}]\!] \mid f(0) \in D\}$ and $D + [\![I^{\Gamma^*,\leq}]\!] = \{f \in [\![D^{\Gamma,\leq}]\!] \mid$ the coefficients of nonconstant terms of f belong to $I\}$. In this talk, we give some conditions for the rings $D + [\![E^{\Gamma^*,\leq}]\!]$ and $D + [\![I^{\Gamma^*,\leq}]\!]$ to be Noetherian or to satisfy the ascending chain condition on principal ideals. (Received September 11, 2013)

1096-VJ-1102 **Whitney Klaryn George***, Department of Mathematics, West Chester University, West Chester, PA 19383. *Twist Knots and Thickenings.*

We will sketch a proof that any neighborhood of a positive twist knot K_m with $m \geq 3$ and odd with extremal Euler number can be thickened to a standard neighborhood of a maximal Thurston-Bennequin number Legendrian representative of K_m. In particular, we will investigate the restrictions on the twist number and on the neighborhoods which lead to open questions. (Received September 12, 2013)

1096-VJ-1222 **Weam M. Al-Tameemi** (weam.altameemi@tamiu.edu*), 5201 University Blvd., LBV 312, Laredo, TX 78041, and **Robert R. Kallman** (kallman@unt.edu), 1155 union Circle 311430, Denton, TX 76203. *$R^n x$ $G(n)$ is Algebraically Determined.* Preliminary report.

Let G be a Polish group. G is algebraically determined Polish group if given any Polish group L and an algebraic isomorphism f : L -> G, then f is a topological isomorphism. Let M(n;R) = $\mathrm{R}^{(n)^2}$ be all n x n matrices with coefficients in R, and let the group G in the above definition be the natural semidirect product R^nx G(n), where n >= 2 and G(n) is one of the following groups: either the general linear group GL(n;R) = A in M(n;R) | det(A)is not zero, or the special linear group SL(n;R)=A in GL(n;R) | det(A) = 1, or |SL(n;R)| = A in GL(n;R) | |det(A)| = 1, or GL^+(n;R) = A in GL(n;R) | det(A) > 0. We will prove that the natural semidirect product R^nx G(n) is an algebraically determined Polish group. In addition, a key intermediate result that requires a fair amount of labor is to prove that f^{-1}(SO(n;R)) is an analytic subgroup of L, where SO(n;R) is the n x n rotation group with determinant one and SO(n;R)subset of SL(n;R)subset of G(n) for every n >= 2. The proofs are somewhat delicate, for there are nontrivial natural semidirect products that are not algebraically determined. For example, the natural semidirect product R^3 x SO(3;R) surprisingly has a discontinuous automorphism. Also, GL(n;R) is not algebraically determined Polish group. (Received September 13, 2013)

1096-VJ-1275 **Chad Awtrey*** (cawtrey@elon.edu), **Brett Barkley**, **Jeremy Guinn** and **Mackenzie McCraw**. *Absolute resolvents for quartic polynomials.*

An important problem in computational algebra is to determine the Galois group of an irreducible polynomial. If we restrict to the setting of degree 4 polynomials, then most accounts in the literature make use of the "cubic resolvent". In this talk, we discuss all possible absolute resolvents for quartic polynomials (of which the cubic resolvent is one example). We show there is a unique such resolvent the degrees of whose irreducible factors completely determines the Galois group of the original quartic polynomial. (Received September 14, 2013)

1096-VJ-1309 **Steven Clontz*** (clontsc@auburn.edu), Auburn University, AL. *Characterizing Covering Properties Using Limited Information Strategies for Topological Games.*

Two topological games $LF_{KP}(X)$ and $LF_{KL}(X)$ due to Gary Gruenhage proceed as follows: each round, the first player K chooses a compact set in X, followed by the second player P (resp. L) choosing a point (resp. compact set) in X which misses every compact set chosen by K previously. The game proceeds for ω-many rounds, and K wins the game if the points (resp. compact sets) chosen by her opponent are locally finite in X. For locally compact X, various covering properties are characterized by the presence of winning limited information strategies for player K, strategies which only require partial memory of the history of the opponent's moves. In addition, by investigating these limited information strategies, we obtain a novel proof of the equivalency of various covering properties in locally compact spaces: X is Lindelöf iff X is σ-compact iff X is hemicompact. We will introduce these games and demonstrate the intuition behind these results, which were part of the speaker's early work toward his dissertation. (Received September 14, 2013)

1096-VJ-1312 **Jordan Alexander*** (jordan_alexander@baylor.edu). *On a wonderful correspondence between Hilbert series of unitarizable highest weight modules.* Preliminary report.

The notion of quasi-dominance was introduced by Enright and Willenbring as a class of weights whose corresponding unitarizable highest weight modules, when they exist, have strikingly elegant Hilbert series. Specifically, the Hilbert series $H_L(t)$ of the unitarizable highest weight module $L(\lambda)$, with λ quasi-dominant, is given by

$$H_L(t) = R \cdot \frac{H_E(t)}{(1-t)^D}$$

where E is a finite-dimensional simple module closely related to L, R is a particular rational number, and D is a particular natural number. The Wallach representations embody the particularly nice property that R is equal to one, and the purpose of this paper is to analyze the set of unitarizable highest weight modules satisfying this condition. (Received September 14, 2013)

1096-VJ-1425 **Timothy E Goldberg*** (timothy.goldberg@gmail.com), Lenoir-Rhyne University, LR Box 7141, Hickory, NC 28603. *Algebraic structure in the card game SET.* Preliminary report.

The card game SET has often been studied as a rich source of combinatorial and probabilistic questions, and also as a beautiful and hands-on example of a finite geometry. In fact, SET also possesses an interesting algebraic structure: there is a natural binary operation on the cards in SET, which is commutative but possesses no identity and is not even associative. In this talk, the speaker will describe this algebraic structure and its properties, and show that it is an involutory quandle. The proof of this fact follows largely from an understanding of the geometric structure of SET. This talk should be accessible to an undergraduate audience. (Received September 15, 2013)

1096-VJ-1699 **Carl Olimb***, carl.olimb@smsu.edu. *Use of Topological Data Analysis to investigate species connectivity in the Northern Great Plains Ecoregion.* Preliminary report.

Identification of wildlife corridors in the Northern Great Plain Ecoregion is a key component when assisting migratory wildlife in dealing with landscape change due to habitat fragmentation and climate change.

Various methods for identifying corridors exist, all of which have serious limitations impacting the scale and accuracy of their output. We propose a topological method. Namely, we use Topological Data Analysis to identify connections between suitable habitat areas. (Received September 16, 2013)

1096-VJ-1705 **Ik Jae Lee*** (leei@rowan.edu), Department of Mathematics, Rowan University, Glassboro, NJ 08028. *Algebra with Anyonic Braiding.* Preliminary report.

For any $\xi \in \mathbb{C}^*$, the family of linear maps given on homogeneous elements by

$$\sigma(a \otimes b) = \xi^{|a||b|}\, b \otimes a$$

defines a braiding on the category of $\mathbb{Z}$-graded complex vector spaces. If $|\xi| = 1$ due to relation to the (2+1)-dimensional physics (cf. the fractional quantum Hall effect), such a braiding is called an **"anyonic braiding"**. In this talk, we explore what happens to algebra with anyonic braiding. (Received September 16, 2013)

1096-VJ-1707 **Scott Lacy*** (scott.lacy@mavs.uta.edu). *Looking Glass 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. In his 1948 paper L.J. Paige presented all known results with his own contributions in admissible groups and planar neofields. The notion of a property D neofield was introduced by A.D Keedwell in his 1966 paper in relation to orthogonal latin squares.

Property D neofields are known to exist for every order up to 20, except 2 and 6, and are believed to exist for every finite order greater than 20. In this talk we discuss a class of commutative property D neofields, and in particular examine a set of commutative property D neofields of order 2^k+1 for all k>2. We will also reflect on more recent research, which has been partially supported by the National Science Foundation GK-12 Program. (Received September 16, 2013)

1096-VJ-1790 **Gregory J. Clark*** (clargj22@wclive.westminster.edu), Westminster College, Box 592, New Wilmington, PA 16172. *An Algebraic Approach to Annular Tilings.*

A *tile invariant* is a linear relation among the number of copies of each tile used in any tiling of a given region. Furthermore, the *tile counting group*, a group whose elements are the tile invariants for a given set of tiles over a group of regions, can be thought of as a quotient group. We have proven that the tile counting group for the set of skew and T-tetrominoe tiles over annular regions of width 2, defined as the quotient group $\mathbb{Z}^8/\mathcal{I}$, is isomorphic to $\mathbb{Z}^3 \times \mathbb{Z}_2$. In this talk we will work through the construction of $\mathcal{I}$, the group of differences among the tile counts that can arise from any 2 tilings of a given region in our family. In particular, we will explain how the elements of $\mathcal{I}$ can be generated using only five elements. (Received September 16, 2013)

1096-VJ-1880 **Amanda Bright*** (abright.14@westminster-mo.edu), **Gregory Clark**, **Brian Keating**, **Brian Whetter**, **Kyle Evitts** and **Levi Altringer**. *Tile Counting Group by Invariants.*

For a given set of n tiles over a region, a tile invariant is a function of the appearances of the tiles in any tiling of the region. We define the subgroup I of $\mathbb{Z}^n$ to be the differences between the tile counts that can arise from any two tilings of a given region. The tile counting group, $\mathbb{Z}^n/I$, tells us the size of the group of tile invariants of the tile set over our regions. We will discuss how the tile counting group, $\mathbb{Z}^8/I$, is proven for the tile set of all skew and t-tetrominoes over annular regions of width 2. Our results will show $\mathbb{Z}^8/I$ is isomorphic to $\mathbb{Z}^3 \times \mathbb{Z}_2$. (Received September 16, 2013)

1096-VJ-1907 **Yasanthi Kottegoda*** (yasanthi_k@yahoo.com). *The number of zeros of linear recurring sequences over finite fields.* Preliminary report.

I discuss the possible number of zeros of a linear recurring sequence over a finite field $\mathbb{F}_q$, based on an irreducible polynomial of degree d and order m as the characteristic polynomial. I give upper and lower bounds on the cardinality of the set of number of zeros. The set is determined when $t = (q^d - 1)/m$ has the form $q^a + 1$ or $q^{2a} - q^a + 1$. The connection with coding theory is a key ingredient. (Received September 16, 2013)

1096-VJ-2243 **L. K. Lauderdale*** (lklauder@ufl.edu), Department of Mathematics, 358 Little Hall, PO Box 118105, Gainesville, FL 32611. *Lower Bounds on the Number of Maximal Subgroups in a Finite Group.*

For a finite group G, let $m(G)$ denote the set of maximal subgroups of G and $\pi(G)$ denote the set of primes which divide $|G|$. When G is a cyclic group, an elementary calculation proves that $|m(G)| = |\pi(G)|$. In this paper, we prove lower bounds on $|m(G)|$ when G is not cyclic. In general, $|m(G)| \geq |\pi(G)| + p$ where $p \in \pi(G)$ is the smallest prime that divides $|G|$. If G has a noncyclic Sylow subgroup and $q \in \pi(G)$ is the smallest prime such that $Q \in \mathrm{Syl}_q(G)$ is noncyclic, then $|m(G)| \geq |\pi(G)| + q$. Both lower bounds are best possible. (Received September 17, 2013)

1096-VJ-2250 **Ryan T Johnson*** (rjohnson@iastate.edu), 641 49th Street, Apt 2, Des Moines, IA 50312. *Indicator of Tambara-Yamagami Categories.*

The Frobenius-Schur indicator is an invariant of spherical fusion categories. A particular class of spherical categories are Tambara-Yamagami categories. I will present my result that the Frobenius-Schur indicator is in fact a strong invariant of Tambara-Yamagami categories. (Received September 17, 2013)

1096-VJ-2257 **Hoon Hong** (hong@ncsu.edu), **James Rohal*** (jjrohal@ncsu.edu), **Mohab Safey El Din** (mohab.safey@lip6.fr) and **Éric Schost** (eschost@uwo.ca). *Connectivity in Semialgebraic Sets.* Preliminary report.

A semialgebraic set is a subset of real space defined by polynomial equations and inequalities and is a union of finitely many maximally connected components. We consider the problem of deciding whether two given points in a semialgebraic set are connected; that is, whether the two points lie in a same connected component. In particular, we consider the semialgebraic set defined by $f \neq 0$ where f is a given nonzero polynomial. The motivation comes from the observation that many important or non-trivial problems in science and engineering can be often reduced to that of connectivity. Due to its importance, there has been intense research effort on the problem. We will describe a method based on gradient fields and provide a proof of correctness using ideas from Morse theory. We give a bound on the length of a path connecting two points lying in a same connected component. (Received September 17, 2013)

1096-VJ-2389 **Emma Norbrothen*** (emnorbrothen@plymouth.edu). *On Classifying the Double Cosets $H_k\backslash G_k/H_k$ of* $\mathrm{SL}(2,k)$.

A symmetric space is defined as the homogenous space G/H, where G is a reductive group and H is the fixed point group of an involution. The generalization to arbitrary fields is called a symmetric k-variety, which is similarly defined as the G_k/H_k, where G_k and H_k are the k-points of G and H, and k is not necessarily algebraically closed. The action of H_k on G_k/H_k can be seen as the double cosets $H_k\backslash G_k/H_k$. We are classifying this action for $G = \mathrm{SL}(2,k)$, with an emphasis on the finite and p-adic fields. (Received September 17, 2013)

1096-VJ-2653 **Lee Stemkoski*** (stemkoski@adelphi.edu), Department of Mathematics & Computer Science, Adelphi University, Garden City, NY 11530, and **Salvatore P Giunta** (sgiunta@adelphi.edu). *Classifying Families of Polynomial Knots.* Preliminary report.

Polynomial knots are embeddings of $\mathbb{R}$ in $\mathbb{R}^3$, where the coordinate functions of the embedding are polynomials. The one-point compactifcation of such curves are topological knots. For a parametrization with polynomials of fixed degree, we investigate the space of coefficients of the polynomials. We find algebraic equations for the boundaries of regions corresponding to knots parameterized by various families of odd and even polynomials of degree at most seven. We also present an algebraic characterization of Reidemeister moves and present some conjectures and avenues for further investigation. (Received September 17, 2013)

1096-VJ-2708 **Amanda Taylor*** (taylor@math.binghamton.edu), Department of Mathematical Sciences, Binghamton University, Binghamton, NY 13902-6000. *Locally Solvable Subgroups of PLo(I).*

A locally solvable group is a group in which every finitely generated subgroup is solvable. Using a geometric criterion that is equivalent to local solvability in PLo(I), we sketch a proof that locally solvable subgroups of PLo(I) are countable. The result also holds for Thompson's Group F and some of its generalizations, as they are subgroups of PLo(I). The hope is that this work, along with further research about classifying locally solvable subgroups, will be a step toward solving conjectures surrounding elementary amenable subgroups of PLo(I), hence F and its siblings. (Received September 18, 2013)

General Session on Research in Analysis

1096-VK-840 **Thomas J Osler*** (osler@rowan.edu), Mathematics Department, Rowan University, Glassboro, NJ 08028. *A fresh look at some very old formulas for pi.*

Vieta's product for 2 /Pi has factors that are nested radicals. The Wallis product for 2 /Pi has factors that are rational numbers. Brouncker gave an infinite sequence of continued fractions for 4 /Pi . By summarizing some recently published results in this expository paper, we show that these seemingly unrelated results are connected. We give a general formula in which the products of Vieta and Wallis are special cases. We give another general formula of which the results of Brouncker and Wallis are special cases. Both formulas allow us to "morph" from one result to the other. (Received September 10, 2013)

1096-VK-1022 **J. Alan Alewine*** (jaalewine@mckendree.edu). *Rates of Uniform Convergence for Riemann Integrals.*

We discuss various rates of uniform convergence for Riemann integrals. As a lemma, we show that any function of bounded variation can be approximated uniformly by a step function whose variation is approximately that of the original function. (Received September 12, 2013)

1096-VK-1229 **Hong Biao Zeng*** (hzeng@fhsu.edu), Department of Mathematics & Computer Science, 600 Park ST, Hays, KS 67601, and **Mohammad Riazi-Kermani**. *On a Geometric Power Series.*

In this paper, we study the closed formula for the following geometric power series: $F_k(x) = \sum_{n=1}^{\infty} x^n n^k$ where $|x| < 1$, $x \neq 0$, and k is a non-negative integer. The main result states that $F_k(x) = \sum_{i=1}^{k} c_{i,k} \frac{i!x^i}{(1-x)^{i+1}}$ where $c_{i,k}$ are the Stirling numbers of the second kind, i.e. $c_{i,k} = \frac{1}{i!}\sum_{j=0}^{i}(-1)^{i-j}\binom{i}{j}j^k$ (Received September 13, 2013)

1096-VK-1952 **Haripriya Chakraborty*** (priyach@udel.edu), Newark, DE 19716, and **Jason D. Mireles-James** (jmireles@math.rutgers.edu), New Brunswick, NJ 08854. *Connecting Orbits of Complex Analytic Maps.*

In this talk, we analyze homoclinic connecting orbits for some complex analytic maps, in order to approximate the Julia sets of the maps from below. For a given complex analytic map on an open disk, we consider the fixed point, which may be repelling or attracting, and explicitly solve Schroder's equation using a computer assisted argument. This leads to a high order polynomial approximation of the conjugacy map with mathematically rigorous computer assisted error bounds. Once the conjugacy map has been computed, we reformulate the homoclinic orbits as solutions of a certain nonlinear equation, which we again analyze using rigorous numerics. We discuss results for the quadratic map and an exponential map as examples. (Received September 16, 2013)

1096-VK-2006 **Francisc Bozgan** (franciscdodo@yahoo.com), **Anthony Sanchez*** (anthony.sanchez.1@asu.edu), **Cesar Silva** (cesar.e.silva@williams.edu), **David Stevens** (david.f.stevens@williams.edu) and **Jane Wang** (jywang@princeton.edu). *On the Classification of W-Measurably Sensitive Actions.* Preliminary report.

Notions of sensitivity for measurable dynamical systems have been studied recently by several authors. Grigoriev, Iordan, Lubin, Ince and Silva proved a dichotomy theorem for conservative, ergodic nonsingular endomorphisms in terms of W-measurable sensitivity. We study this classification in the context of nonsingular N^d actions. (Received September 18, 2013)

1096-VK-2213 **Gabriel T Prajitura***, Mathematics Department, SUNY Brockport, 350 New Campus Drive, Brockport, NY 14420. *A Leibniz Test.*

We will preset a version of the Leibniz Test for series which is independent of the alternation of signs and of a decreasing property for the summed sequence. (Received September 17, 2013)

1096-VK-2523 **Robert F. Allen*** (rallen@uwlax.edu), University of Wisconsin-La Crosse, Department of Mathematics, La Crosse, WI 54601, **Katherine C. Heller** (kheller@noctrl.edu), North Central College, Department of Mathematics, Naperville, IL 60540, and **Matthew A. Pons** (mapons@noctrl.edu), North Central College, Department of Mathematics, Naperville, IL 60540. *Multiplication Operators on S^2.* Preliminary report.

We investigate the multiplication operators acting on $S^2(\mathbb{D})$, the space of analytic functions on $\mathbb{D}$ whose derivative is in $H^2(\mathbb{D})$. We characterize boundedness and compactness, establish estimates on the operator norm, and determine the spectrum. We study the commutant and the convexity of the bounded multiplication operators on S^2. Lastly we characterize the isometric multiplication operators. (Received September 17, 2013)

General Session on Research in Applied Mathematics

1096-VL-16 **Ismail T Ali*** (taqi@sci.kuniv.edu.kw), Kuwait University, Dept. Mathematics, P.o.Box 5969, 13060 Safat, Kuwait. *Generalized Fractional Kinetic equations: Solutions and applications.* Preliminary report.

Fractional Kinetic equations have gained considerable importance during the last decade, due to their importance in certain problems in science and engineering[J.H.Haubold and A.M.Mathai: The fractional kinetic equations and thermonuclear functions, Astrophysics Space Science 273(2000), 53-63; R.K. Saxena and S.L.Kall: On the solution of certain fractional kinetic equations, Applied mathematics and computation, 119(2008),504-511]. We plan to survey results related to such problems. Further, we obtain solution of some generalized fractional kinetic equations and express such solutions in terms of cetain Hypergeometric functions. (Received April 23, 2013)

1096-VL-349 **Pablo U Suarez*** (psuarez@desu.edu), Delaware State University, 1200 N Dupont Hwy, Dover, DE 19709. *Effect of general conductivities in Magneto Rotational Instability.* Preliminary report.

In studying the Taylor Couette problem in the presence of a magnetic field many author's assume that the conductivities σ of the walls are either perfectly insulating $\sigma = 0$ or perfectly conducting $\sigma \to \infty$. In this work, we do not assume these ideal cases and study what happens to the stability of the fluid if the conductivity of the walls are allowed to vary. With "finite" conductivities an eigenvalue problem with the eigenvalue appearing in the boundary conditions is obtained. The resulting problem is solved numerically by using the Chebyshev Spectral Method together with an iterative scheme. (Received August 29, 2013)

1096-VL-387 **Brandon J Hutchison*** (brandon.hutchison@uafs.edu), 5210 Grand Avenue, P.O. Box 3649, Ft. Smith, AR 72913, and **Mark Arnold**. *A Restarted Homotopy Method for the Nonsymmetric Eigenvalue Problem.*

The eigenvalues and eigenvectors of a Hessenberg matrix H are computed with a combination of homotopy increments and the Arnoldi method. Given a set, Ω, of approximate eigenvalues of H, there exists a unique vector $f = f(H, \Omega) \in \mathbb{R}^n$ where $\lambda(H - e_1 f^t) = \Omega$. A diagonalization of the homotopy $H(t) = H - (1-t)e_1 f^t$ at $t = 0$ provides a prediction of the eigenvalues of $H(t)$ at later times. These predictions define a new Ω that defines a *new homotopy*. The correction for each eigenvalue has an $O(t^2)$ error estimate, enabling variable step size and efficient convergence tests. Computations are done primarily in real arithmetic, and bifurcations are avoided by restarting the homotopy with Arnoldi eigenvalues. Although the method is neither as elegant nor as robust as the QR algorithm, it is competitive in terms of flops in the randomly generated examples considered and is parallelizable. (Received September 01, 2013)

1096-VL-475 **Jayant Singh*** (jayant.singh@ndsu.edu). *A new method for Stability Analysis of Discrete time Recurrent Neural Networks.*

Recurrent Neural Networks (RNN) have diverse applications such as pattern recognition, artificial intelligence etc.So, it is imperative to address the stability problem of RNN.To date, various attempts have been made to develop stability criteria for discrete time RNN.Most of them are based on the classical results of theory of absolute stability, which is not very universal. We are trying to develop a stability criterion based on concept of Reduction of Dissipativity Domain (RODD). This approach has been tested with examples. (Received September 04, 2013)

1096-VL-619 **Ravi Shankar*** (r.shankar997@gmail.com), Department of Chemistry, UC Davis, Davis, CA 95616, **Peter Haine**, Department of Mathematics, Massachusetts Institute of Technology, Cambridge, MA 02139, **Abigail Gartrell**, Department of Mathematics, University of Maryland, College Park, MD 20740, and **Alberto Mojica**, **Nathan Loker** and **Sergei Fomin**, Department of Mathematics and Statistics, CSU Chico, Chico, CA 95929. *Stability Analysis of Non-Newtonian Rimming Flow.*

In application to rotational molding of thin polymer films, the rimming flow of a thin layer of fluid is studied using theoretical models. Non-Newtonian shear-thinning and visco-elastic memory effects characteristic to many polymers are taken into account with various quasi-linear constitutive models. For each type of fluid, the stability of the films to small perturbations is studied analytically using linear theory. Explicit results are obtained in each case and validated against numerical solutions of the fully nonlinear disturbances relation. Shear-thinning films are shown to be neutrally stable. Visco-elasticity is shown to stabilize thin films. (Received September 08, 2013)

1096-VL-789 **A D Clark*** (adclark@mail.com), **K Chang**, **R S Gejji**, **S Chrihalmeanu** and **A A Ross**. *Methodological Insights to Exploring the Stability of General and Photorealistic Models of the Pupil Light Reflex (PLR).* Preliminary report.

We explore the stability of two main mathematical frameworks of the pupil light reflex (PLR) via the Lambert $\mathcal{W}$ function. As a result, we can obtain a more comprehensive stability regime in terms of the delay and gain of the negative feedback system. We also apply this approach to explore the stability of extended models of the PLR where we incorporate the iris musculature effects. This work is not only an improvement on the related research on this topic, but has several applications in the fields of mathematical biology, computer graphics, and biometrics. In biometrics, particularly in the area of iris recognition, our work will aide the National Institute of Standards and Technology's (NIST's) efforts for understanding the effects of dilation on iris recognition. Additionally, our work will serve the Department of Homeland Security (DHS) in providing avenues of mitigating the effects of iris dilation on matching performance for border control scenarios. (Received September 10, 2013)

1096-VL-833 **Ranadhir Roy*** (rroy@utpa.edu), Mathematics Department, University of Texas Pan American, 1201 West University Drive, Edinburg, TX 78539, and **Daniel N Riahi**. *Investigate the charactertics of blood flow in brain tumor using Finite Element methods.*

Many brain tumors are highly invasive and therefore extremely difficult to treat. In order to prevent the reoccurrence of tumor cells, anticancer drugs are used after surgery. Many studies have demonstrated a better outcome with concurrent application of radiotherapy and chemotherapy. Thus combined radiotherapy and chemotherapy treatment can improve the survival rate. Our major objective in this work is to understand the physiology of blood flow in a brain tumor, and also to investigate the effect of concurrent application of two anti-cancer drugs in a brain tumor. Drug transport in the tumor interstitial depends on convection and diffusion. To investigate characteristics of blood flow through a spherical tumor, a couple convection-diffusion-reaction models for simulating interaction between two anti cancer drugs has been developed. The governing equations with appropriate boundary conditions are used for brain tumor geometry. The interstitial fluid pressure, velocity and drugs concentration are calculated using a finite element method. Triangular elements are used to solve these problems. The finite element solution of this problem is presented and demonstrated that our numerical techniques can solved convection diffusion equations. (Received September 10, 2013)

1096-VL-891 **Jeffrey M Larson*** (jeffreyl@kth.se), Osquldas väg 10, Floor 6, 100-44 Stockholm, Sweden. *Large-scale Coordinated Platooning of Heavy-duty Vehicles.*

Heavy-duty vehicles traveling in platoons experience less aerodynamic drag and therefore consume fuel at a slower rate than when traveling alone. We present a coordinated approach for routing vehicles to minimize total fuel use (and thereby minimize their environmental impact). Though we show the general platooning problem to be NP-hard, we propose a heuristic based on local controllers placed throughout the road network that facilitate platoon formations with minimal information. By knowing a vehicle's position, speed, and destination, the local controller can quickly decide how the vehicle's speed should possibly be adjusted to platoon with others in the near future. We solve this optimal control and routing problem exactly for real-world scenarios. By implementing our distributed control system on a large-scale simulation of the German autobahn road network, we observe fuel savings ranging from 1-9%, with savings exceeding 5% when only a few thousand vehicles participate in the system. (Received September 11, 2013)

1096-VL-1071 **Thomas Bellsky*** (bellskyt@asu.edu), Arizona State University, School of Mathematical and Stat. Sciences, Physical Sciences, A-Wing, P.O. Box 871804, Tempe, AZ 85287-1804. *Reduced uncertainty by targeting observations with the Kalman filter.*

We demonstrate that targeting observations with various Kalman filter data assimilation techniques can significantly reduce analysis uncertainty for both linear and nonlinear dynamical systems. First, we investigate the traditional Kalman filter for a linear model, and prove an explicit formula for the analysis uncertainty, which describes the update to the analysis uncertainty with m observations as m rank-one corrections. Additionally, we show that increasing the number of observations will always reduce analysis uncertainty. Next, we provide numerical results for two nonlinear model problems of potential meteorological interest. These numerical results demonstrate that the local ensemble transform Kalman filter (LETKF) with targeted observations based on largest ensemble variance is more skillful in reducing analysis uncertainty than the LETKF with randomly located observations. (Received September 12, 2013)

1096-VL-1215 **Otis C. Wright, III*** (wrighto@cedarville.edu), Department of Science and Mathematics, 251 N. Main St., Cedarville, OH 45314. *Elliptic solutions of a coupled nonlinear Schrödinger system.*

It is well-known that elliptic functions can be used to construct explicit quasiperiodic solutions of an integrable system of two coupled nonlinear Schrödinger equations, known as the Manakov equation, which arises in the dispersive propagation of waves in widely disparate applications such as optical fibers, Bose-Einstein condensates and crowd dynamics. The nonlinear partial differential equations are equivalent to the commutation of two linear differential operators, known as a Lax pair, which are used to integrate the coupled equations. Elliptic solutions arise by assuming that a certain stationary matrix operator simultaneously commutes with the two differential operators of the Lax pair. The eigenvalues of the matrix operator form a meromorphic function on a trigonal Riemann surface of genus one. In this talk it will be shown how straightforward algebra can be used to obtain not only explicit quasiperiodic solutions but also a complete description of the parameter space of solutions with real quasiperiod, together with their limiting forms and qualitative information about the internal polarization of the waveform. (Received September 13, 2013)

1096-VL-1406 **Wufeng Tian*** (wtian@crimson.ua.edu), Tuscaloosa, AL 35487, and **Shan Zhao** (szhao@bama.ua.edu), Tuscaloosa, AL 35487. *A fast ADI algorithm for geometric flow equations in bio-molecular surface generation.*

A new alternating direction implicit (ADI) method is introduced to solve potential driven geometric flow partial differential equations (PDEs) for bio-molecular surface generation. For such PDEs, an extra factor is usually added to stabilize the explicit time integration. Based on a scaled PDE model, there are two existing ADI schemes involved with cross derivative terms that have to be evaluated explicitly. It affects the stability and accuracy of these ADI schemes. To overcome these difficulties, we propose a new ADI algorithm based on the un-scaled form so that cross derivatives are not involved. The proposed ADI algorithm is validated through benchmark examples with analytical solutions, reference solutions, or literature results. Moreover, quantitative indicators of a bio-molecular surface, including surface area,surface-enclosed volume and solvation free energy, are analyzed for various proteins. The proposed ADI method is found to be unconditionally stable and more accurate than the existing ADI schemes in all tests. This enables the use of a large time increment in the steady state simulation so that the proposed ADI algorithm is very efficient for bio-molecular surface generation. (Received September 16, 2013)

1096-VL-1634 **Mark J Panaggio***, markpanaggio2014@u.northwestern.edu, and **Daniel M Abrams**.
Chimera states on periodic spaces.

Diverse phenomena ranging from the blinking lights of fireflies to the footfalls of pedestrians on a bridge to the firing of nerve cells in the brain can be modeled as arrays of coupled oscillators. Although incoherence and synchronization are the norm in these arrays, complex spatiotemporal patterns such as "chimera states"—where incoherence and coherence coexist—have been observed both computationally and experimentally in a variety of systems. I will use an analytical approach to characterize various types of chimera states (including stripes, spots and spirals) that have been observed in two-dimensional periodic spaces, and discuss the relationship between the coupling scheme and the stability of these exotic dynamic patterns. (Received September 16, 2013)

1096-VL-1733 **Eva Marie Strawbridge*** (strawbem@jmu.edu), James Madison University, Department of Mathematics and Statistics, MSC 1911, Harrisonburg, VA 22807, and **Charles Wolgemuth**. *The compatibility of slender bodies and surface traction at low Reynolds number.*

The past forty years have witnessed an ever-increasing interest in applications of slender-body dynamics (such as Kirchhoff rod theory), in particular with regard to the shape, movement, or material parameters of biomolecules or materials. In most applications, hydrodynamic interactions (i.e. surface traction often approximated by resistive force theory) have been of utmost importance since the biologically relevant scales usually result in very small Reynolds number. However, the formulation of classical Kirchhoff slender-body assumes no surface traction in the development of the constitutive relation. We will discuss an asymptotic approach to reconciling this apparent inconsistency and provide velocity bounds for which the compatibility of Kirchhoff rod and resistive force theory hold. (Received September 16, 2013)

1096-VL-2018 **Daniel Patrick Howard*** (dphoward@wisc.edu), 118 Buck Cole, 625 Elm Drive, Madison, WI 53706-1183, and **Keith J Wojciechowski** (wojciechowskik@uwstout.edu), 202D Jarvis Hall - Science Wing, 410 10th Avenue East, Menomonie, WI 54751-2506. *Applying the Eigendecomposition Pseudospectral Method to Wave Propagation Problems.*

In this talk we demonstrate the range and applicability of the eigen-decomposition pseudospectral (EPS) method to a variety of linear and nonlinear PDEs. The derivative matrix construction for the EPS method is based on representing the derivative operator as an integral kernel composed of singular functions so the matrices naturally incorporate the boundary conditions of the problem and do not rely on the interpolating polynomials. If the boundary conditions of the application are not encompassed by the natural boundary conditions of the operator, we show how to modify the method to accommodate these circumstances. Moreover, we demonstrate how this modification can be used to incorporate the EPS method in a domain decomposition setting. We show that the construction achieves similar or better accuracy than traditional pseudospectral derivative matrices, while resulting in a norm that is orders of magnitude smaller than the standard construction. (Received September 17, 2013)

1096-VL-2080 **Joon Hyuk Kang*** (kang@andrews.edu), Department of Mathematics, Andrews University, Berrien Springs, MI 49104. *Coexistence condition of two species of animals residing in an environment.*

Two species of animals are competing in the same environment. Under what conditions do they coexist peacefully? Or under what conditions is either one of the two species become extinct, that is, either one of the two species excluded by the other? It is natural to say that they can coexist peacefully if their reproduction rates and self-limitation rates are relatively larger than those of competition rates. In other words, they can survive if they interacts strongly among themselves and weakly with others. We investigate this phenomena in the mathematical point of view by modeling of a system of Partial Differential Equations. (Received September 17, 2013)

1096-VL-2135 **Aminur Rahman*** (ar276@njit.edu), 323 Martin Luther KIng Jr.Blvd, Newark, NJ 07102. *Peixoto's Structural Stability Theorem: The One-dimensional Version.*

Peixoto's structural stability and density theorems represent milestones in the modern theory of dynamical systems and their applications. Despite the importance of these theorems, they are often treated rather superficially, if at all, in upper level undergraduate courses on dynamical systems or differential equations. This is mainly because of the depth and length of the proofs. In this note/module, we formulate and prove the one-dimensional analogs of Peixoto's theorems in an intuitive and fairly simple way using only concepts and results that for the most part should be familiar to upper level undergraduate students in the mathematical sciences or related fields. The intention is to provide students who may be interested in further study in dynamical systems with an accessible one-dimensional treatment of structural stability theory that should help make Peixoto's theorems and their more recent generalizations easier to appreciate and understand. (Received September 17, 2013)

1096-VL-2168 **Ting Wang*** (ting1@umbc.edu), Baltimore, MD 21250, and **Muruhan Rathinam** (muruhan@umbc.edu), Baltimore, MD 21250. *Analysis of Monte Carlo methods for computing parametric sensitivities in stochastic chemical kinetics.* Preliminary report.

Intracellular chemical reactions are best modeled by a Markov process in continuous time with the non-negative integer lattice as state space. The jump rates typically depend on certain system parameters. Computing the parametric sensitivity of system's behavior is essential in determining robustness of systems as well as in estimating parameters from observed data.

Monte Carlo methods for numerical computation of parametric sensitivities fall into three categories: finite difference (FD) methods, pathwise derivative (PD) method and the Girsanov transform (GT) method. It has been numerically observed in chemical kinetics applications as well as in other fields such as Operations Research that the PD method when applicable is more efficient (has lower variance) than the GT method. We provide a theoretical explanation as to why this is the case.

We provide both analysis and numerical results showing that for a class of Markov processes known as density dependent processes, the efficiency of the GT method scales as $\mathcal{O}(N^{1/2})$ while that of a regularized PD method and most FD methods scale as $\mathcal{O}(N^{-1/2})$, where N is the system size parameter. In many practical systems N is modestly large and as such one expects the GT method to be not very efficient. (Received September 17, 2013)

1096-VL-2174 **Nolisa S. Malluwawadu*** (nsmalluwawad@ualr.edu), Department of Mathematics & Statistics, University of Arkansas at Little Rock, 2801 South University Avenue, Little Rock, AR 72204-1099, **Xiaoshen Wang** (xxwang@ualr.edu), Department of Mathematics & Statistics, University of Arkansas at Little Rock, 2801 South University Avenue, Little Rock, AR 72204-1099, **F Gao** (fxgao@ualr.edu), Department of Mathematics & Statistics, University of Arkansas at Little Rock, 2801 South University Avenue, Little Rock, AR 72204-1099, and **Thomas C. McMillan** (tcmcmillan@ualr.edu), Department of Mathematics & Statistics, University of Arkansas at Little Rock, 2801 South University Ave, Little Rock, AR 72204-1099. *A Modified Weak Galerkin Finite Element Method.*

In this paper we introduce a new discrete weak gradient operator and a new weak Galerkin (WG) finite element method for second order Poisson equations based on this new operator. This newly defined discrete weak gradient operator allows us to use a single stablizer which is similar to the one used in the discontinuous Galerkin (DG) methods without having to worry about choosing a sufficiently large parameter. In addition, we'll establish the optimal convergence rates and validate the results with numerical examples. (Received September 17, 2013)

1096-VL-2311 **Evan C Cresswell-Clay*** (ecc15@pitt.edu), 404 Biddle Ave., Pittsburgh, PA 15221, and **G Bard Ermentrout**. *Modeling the Cutaneous Rabbit Effect.*

Perception can be viewed as a competition between stimuli, each stimulated sense vying for its place in the final presentation to its owner. When these senses don't agree you have an illusion. This project models the cutaneous rabbit effect whereby a subject is tapped multiple times in two or more locations on the forearm and perceives false motion (as if a rabbit were hopping across your arm). We attempt to simulate the data on this illusion used by Daniel Goldreich with a mechanistic model based on neural competition. We develop a model consisting of coupled systems of ordinary differential equations representing 20 points partitioned equally along the forearm as they compete for their place in your perception. With the model, we are able to explain much of the perceptual data. (Received September 17, 2013)

1096-VL-2390 **Bubacarr Bah*** (bubacarr.bah@epfl.ch), **Luca Baldassarre** and **Cevher Volkan**. *Model-based Sketching and Recovery with Expanders.*

Sparse signals can be succinctly represented by certain low-dimensional linear sketches with applications in compressive sensing, data streaming and graph-sketching, among others. Recently, structured sparsity has emerged as a promising new tool for reducing sketch size and improving recovery. Existing work on sketching structured sparse signals requires dense sketching matrices. On the other hand, sparse sketching matrices, usually from expanders, are computationally much more efficient, easier to store and apply in recovery. In this paper, we focus on model-based expanders, that is expanders that capture a given structure sparsity model, and show that they exist for a larger class of models than previously considered. We present the first polynomial time algorithm for recovering structured sparse signals from low-dimensional linear sketches obtained via sparse matrices. The algorithm is guaranteed to yield signals with bounded recovery error and is quite easy to implement and customize for structured sparse models that are endowed with a *projection* operator. As a result, we characterize a broad class of structured sparsity models that have polynomial time projection property. We also provide numerical experiments to illustrate the theoretical results in action. (Received September 17, 2013)

1096-VL-2396 **Jonathan Sullivan*** (jonathan.k.sullivan@gmail.com), TX , and **Miguel Cuadros** (miguel_cuadros@att.net), 2715 S. Montreal Ave., Dallas, TX 75224. *Sliding Singularity's of Two-Dimensional Invertible Piecewise Isometries.*

We investigate the singularity of a class of two-dimensional invertible piecewise isometries proposed by A. Gotez, B. Kahng, J. Lowenstein, G. Poggiaspalla and F. Vivaldi. The purpose of this paper is to investigate the sliding singularity, which is known to generate all the complexities of the piecewise isometric systems in this class. We follow the method proposed by B. Kahng and expand the dynamics beyond the original phase space. Through this method, we calculate the sliding ratios of the dynamical systems for the rotation angles $\pi/5$ and $\pi/7$. Incidentally, the sliding ratio of each case turns out to be identical to the corresponding quantity of the symmetric uniform piecewise elliptic rotation map proposed and studied by R. Adler, P. Ashwin, L. Chua, X. Fu, B. Kahng, B. Kitchens, M. Orgorzalek and C. Tresser. (Received September 17, 2013)

1096-VL-2445 **Stephen H. Harnish*** (harnishs@bluffton.edu). *Cluster computing to visualize sound and engineer effective metrics of space and time.*

Using a LittleFe mini-cluster (6 dual-core processors) we visualize molecular dynamics simulations of acoustic waves in Lennard-Jones solids. The employed molecular dynamics code is LAMMPS and visualization tools are AtomEye and VMD. We then analyze the dependence of longitudinal sound wave velocity and frequency peaks on pressure, temperature and wave amplitude. These visualizations and mathematical analyses demonstrate new methods for generating effective spatial and temporal metrics. These metrics are of particular interest to theoretical physicists researching sonic, solid-state analogues of gravity and black holes. This work is a continuation of research funded by the National Science Foundation's Office of CyberInfrastructure through the Blue Waters Undergraduate Petascale Education Program. (Received September 17, 2013)

1096-VL-2479 **Adonis O Ajayi*** (adonisajayi@gmail.com), 150 Kearsney Ct, Village at Blue Hen Apartments, Apartment A6, Dover, DE 19901. *Nonuniform and Adaptive Mesh Refinement Finite-Difference Time-Domain method for Ground Penetrating Radar Simulations.*

We focus on the numerical simulation of electromagnetic wave propagation for Ground penetrating radar (GPR) devices using the Finite-Different Time-Domain (FDTD) method. In many cases, numerical solutions derived from implementation of the standard FDTD method is not without errors of accuracy. For example, the stair-casing error is a major problem of the FDTD method. In order to suppress numerical errors and gain greater efficiency, we apply various techniques such as the effective permittivity (subpixel smoothing), the non-uniform mesh and the Adaptive Mesh Refinement (AMR) techniques. (Received September 17, 2013)

1096-VL-2542 **Ian D Neufer*** (ineufer@asu.edu), 1732 E Alameda Dr, Tempe, AZ 85282, and **Rodrigo B Platte**. *Reconstruction of functions from Fourier data using Gaussian based approximations* Preliminary report.

The conversion between Fourier and image data arises in many applications, such as Magnetic Resonance Imaging (MRI). This talk lays out a novel approach for translating Fourier data by fitting it to a sum of Gaussian functions. Our approach is motivated by the easy transformation of Gaussian functions between Fourier and physical space. The coefficients of the Gaussian functions are obtained by solving a least squares system. Issues that arise are the Gibbs effect which causes wild oscillations around function discontinuities that blur image features, and motion artifacts, which are features not in the object that appear due to movement during the scan. To mitigate the Gibbs Effect, we use first derivative damping and filter our data. Further, our method allows for more flexibility in how data is sampled, which coupled with a future research possibility, spiral sampling, may allow for a reduction in motion artifacts. (Received September 17, 2013)

1096-VL-2635 **Alrazi M Abdeljabbar*** (alrazia@yahoo.com), 10875 Abercorn St. Apt#712, Savannah, GA 31419. *Double Wronskian Solutions for a Generalized (2+1)-Dimensional Boussinesq System with Variable Coefficients.*

The Wronskian technique has been applied to many soliton equations such as the KdV, MKdV, NLS,derivative NLS, KP, sine-Gordon and sinh-Gordon equations. Within Wronskian formulations, soliton solutions and rational solutions are usually expressed as some kind of logarithmic derivatives of Wronskian type determinants and the determinants involved are made of eigenfunctions satisfying linear systems of differential equations. This connection between nonlinear problems and linear ones utilizes linear theories in solving soliton equations. A double Wronskian solution will be given for a Generalized (2+1)-dimensional Boussinesq system with variable coefficients. (Received September 17, 2013)

1096-VL-2636 **Kristyn N. McLeod*** (knmcleod@asu.edu) and **Rodrigo Platte**. *FOURFUN: a new system for automatic computations using Fourier expansions.* Preliminary report.

Using object-oriented programming in MATLAB, a collection of functions, named Fourfun, has been created to allow for quick and accurate approximations of periodic functions with Fourier expansions. To increase efficiency and reduce the number of computations of the Fourier transform, Fourfun automatically determines the number of modes necessary for representations that are accurate close to machine precision. Common MATLAB functions have been overloaded to keep the syntax of the Fourfun class as consistent as possible with the general MATLAB syntax. We show that the system can be used efficiently to solve several differential equations. Comparisons with other systems, such as Chebfun, which is based on polynomial approximations, are provided. (Received September 17, 2013)

1096-VL-2685 **Jessica Ginepro**, **Emma Hartman**, **Ryo Kimura**, **Matthew McDermott*** (mattmcdermott8@gmail.com), **Colin Pawlowski** and **Dylan Shepardson**. *Agent-Based Models for Analyzing Complex Disease Dynamics and Tuberculosis Intervention Cost Effectiveness in the US.*

Mathematical modeling has proven to be a powerful tool when analyzing disease dynamics and assessing various intervention strategies. The most widely used epidemiological models are compartmental differential equation models, variants of the common SIR model. In this work, we investigate the feasibility of modeling real-world disease dynamics with a stochastic, agent-based model. Models of this type more closely mirror real disease dynamics by capturing granularity, population heterogeneity, and stochasticity lost by deterministic compartmental models, but are often thought to be too complex to implement at the population level. Using a previously published 10-compartment differential equation model for validation, we develop an agent-based model of tuberculosis in the United States. To our knowledge, this is the first agent-based model of tuberculosis in the U.S. population, and the only population-level, dynamic model to examine economic implications of tuberculosis. (Received September 17, 2013)

1096-VL-2693 **Michael Herty**, **Alexander Kurganov** and **Dmitry Kurochkin*** (dkurochk@tulane.edu), 1519 Lowerline St., New Orleans, LA 70118. *Numerical Method for Optimization Problems Governed by Hyperbolic Systems of Conservation Laws.*

We develop novel numerical optimization methods for constrained problems governed by nonlinear hyperbolic systems of conservation laws in one space dimension. The optimization problem is equivalent to minimizing an objective cost functional and can be formally viewed as an optimality system of the hyperbolic problem and its adjoint problem. The method requires to numerically solve the hyperbolic system forward in time and a corresponding linear adjoint system backward in time. Numerical results for the control problems constrained by either the Euler equations of gas dynamics or isothermal gas dynamics equations are presented. Both smooth and discontinuous prescribed terminal states are considered. The designed method has been also tested on the scalar inviscid Burgers equation. Convergence properties of the proposed methods are discussed. (Received September 18, 2013)

1096-VL-2713 **Kent William Ehrlich*** (kent.ehrlich@gmail.com), 7136 S 9th St., Phoenix, AZ 85042, and **Eric Kostelich**. *Graph Partitioning Algorithms for Load Balancing on Massively Parallel Computers.*

Data assimilation is the process by which a complex model, such as a global weather forecast model, is updated from a large set of observations. Forecasting operations require that numerical methods for this purpose be able to process millions of observations within a few minutes. The Local Ensemble Transform Kalman Filter is a data assimilation scheme that is designed for efficient operation on massively parallel computers. However, its primary performance bottleneck is poor partitioning of workload, because the geographic distribution of observations in combination with the existing load balancing algorithm creates poorly balanced partitions. This talk describes the use of graph partitioning algorithms, such as METIS, to improve performance by creating good partitions of computational workload which are evenly balanced across potentially hundreds of processors. Conversion of the existing observation data structures into graphs is required to use METIS, but performance benefits in terms of well-balanced workloads make the additional cost of data structure conversions worth the small computation time. (Received September 18, 2013)

1096-VL-2723 **Christina H Lee*** (leec@tcnj.edu), The College of New Jersey, Dept. of Mathematics and Statistics, Ewing, NJ 08550. *Brain Waves.*

This talk describes a study of spiral- and target-like waves traveling in a two-dimensional network of integrate-and-fire neurons with close-neighbor coupling. The individual neurons are driven by Poisson trains of incoming spikes. Each wave nucleates as a result of a fluctuation in the drive. It begins as a target or a spiral, and eventually evolves into a straight "zebra"-like grating. Some of the waves contain defects arising from collisions with other waves. The wavelength and wave speed of the patterns were investigated, as were the temporal power spectra of the oscillations experienced by the individual neurons as waves were passing through them. (Received September 18, 2013)

General Session on Research in Geometry and Linear Algebra

1096-VM-197 **Brice M. Nguelifack*** (bmn0003@auburn.edu), 425 Opelika Rd Apt 261, Auburn, AL 36830, and **Eddy A. Kwessi** and **Asheber Abebe** (bmn0003@auburn.edu), 221 Parker Hall, Auburn, AL 36849. *Generalized Signed-Rank Estimation for Nonlinear Models with Multidimensional Indices.*

We consider a nonlinear regression model when the index variable is multidimensional. Sufficient conditions on the nonlinear function are given under which the Signed-Rank estimators are strongly consistent and asymptotically normally distributed. These sufficient conditions are satisfied by harmonic type functions, which are also of interest in the one dimensional index case where some of results in the current literature are not applicable. (Received August 15, 2013)

1096-VM-362 **Timothy C Melvin*** (tmelvin@carroll.edu), Tim Melvin, 1601 N Benton Ave, Mathematics Department, Helena, MT 59625. *Spectrally Arbitrary Patterns and Algebraic Solutions.*

We say that an $n \times n$ zero-nonzero matrix pattern $\mathbb{A}$ is spectrally arbitrary over the field $\mathbb{F}$ if for every monic, n-degree polynomial $p(t)$ with coefficients from $\mathbb{F}$, there exists a matrix A over $\mathbb{F}$ with zero-nonzero pattern $\mathbb{A}$ such that the characteristic polynomial of A is $p(t)$. We will use Hilbert's Nullstellensatz to show that if a pattern is spectrally arbitrary over $\mathbb{C}$, then it is also spectrally arbitrary over $\overline{\mathbb{Q}}$, the algebraic closure of $\mathbb{Q}$. More generally, this result shows that if any system of multivariate polynomials with algebraic coefficients has a common zero, then there will be a common zero whose components are all algebraic. (Received August 30, 2013)

1096-VM-751 **Matthew L. Wright*** (mlwright@ima.umn.edu). *Hadwiger's Theorem for Functions.*

How can we measure the size of a function? The Lebesgue integral provides a notion of the size of a function, as does the lesser-known Euler integral. Yet there are other notions of function size, in particular, integrals with respect to the intrinsic volumes. The classic Hadwiger Theorem states that any Euclidean-invariant convex-continuous valuation on sets is a linear combinations of the intrinsic volumes. I will lift this result from sets to functions over sets, providing a classification of all valuations on functions, with suitable assumptions about Euclidean-invariance and continuity. Integrals with respect to the intrinsic volumes form a basis for all such valuations, from the topological (the Euler integral) to the geometric (Lebesgue) and everything in between. (Received September 09, 2013)

1096-VM-1146 **William C Abram** (wabram@hillsdale.edu), Department of Mathematics, Hillsdale College, 33 East College Street, Hillsdale, MI 49242, and **Artem Bolshakov*** (atb130030@utdallas.edu). *On the Hausdorff dimension of p-adic Cantor sets.* Preliminary report.

We use techniques from symbolic dynamics and Perron-Frobenius theory to compute the Hausdorff dimension of certain p-adic fractal sets. This work began in the 3-adic case as joint work with Lagarias, intended to address a problem of Erdös. We record tight bounds obtained in the 3-adic case, and report on preliminary findings in the general case. (Received September 13, 2013)

1096-VM-1178 **Kelly Aman***, kelly.aman@mavs.uta.edu. *Determining Properties of Semifields by Investigating Their Cubical Arrays.*

It is well known that a finite semifield, $(S, +, *)$, has p^n elements, for p prime, n a positive integer. Knuth proved that $(S, +)$ can be viewed as an n-dimensional vector space over $GF(p)$, and for any basis, $\{x_1, ..., x_n\}$, of this vector space, $*$ is determined by the $n \times n \times n$ array of scalars, A, satisfying the equation

$$x_i * x_j = \sum_{k=1}^{n} A_{ijk} x_k$$

We will show that two bases define the same cubical array if and only if their associated change of basis transformation is an automorphism of S. The set of all such transformations for a particular cubical array will be isomorphic to Aut(S). Thus, Aut(S) can be determined by examining the cubical arrays generated by all possible bases of S. Since this would be a rather ineffeicient method, we will also discuss methods for limiting the number of bases which need to be investigated. If time permits, preliminary results regarding other uses for the set of cubical arrays of a semifield will be presented. (Received September 13, 2013)

1096-VM-1784 **Yun Myung Oh*** (ohy@andrews.edu), Mathematics Department, Berrien Springs, MI 49103. *Some inequalities on Riemannian submersion and isometric immersions.*

Some of the recent work will be discussed on the submersion invariant $\breve{A}_\pi$ related to the type of the isometric immersion into the ambient space. Several inequalities can be derived based upon the isometric mapping $\phi : M \to \tilde{M}$. (Received September 16, 2013)

1096-VM-1988 **Ivko M Dimitric*** (ivko@psu.edu), 2201 University Drive, Lemont Furnace, PA 15456. *Two old geometrical chestnuts revisited.* Preliminary report.

We examine some variations and generalizations of one geometric problem of Fermat and another (well-known one) by Regiomontanus.

Fermat's geometric poser starts with a rectangle $ABCD$ (vertices labeled clockwise) with ratio of sides equal to $\sqrt{2}$. Construct upon longer side AB as diameter a semicircle on the outside and choose a point P on that semicircle. Consider intersecting points X and Y of PC and PD respectively with AB. To show is that $AX^2 + BY^2 = AB^2$. We generalize this statement for rectangles of different side ratio and examine what happens when the semicircle is replaced by another (quadratic) curve.

The classical problem of Regiomontanus asks to maximize the angle subtended at the eye of an observer moving directly towards a monument by that monument. We examine this problem for different curves of approach to the monument and positions of the monument. (Received September 17, 2013)

1096-VM-2134 **Andrew J. Klimas*** (aklimas@xula.edu), Xavier University of Louisiana, Department of Mathematics, 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 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 of 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 17, 2013)

1096-VM-2226 **Tien Chih*** (tien.chih@umontana.edu), 118 Helena Ct, Missoula, MT 59801. *Classical Linear Optimization in an Abstract Setting.* Preliminary report.

The study of classical linear (or affine) programming gives rise to a very satisfying duality theory, and yields some beautiful results. However, the classical setting takes place in a relatively restrictive setting: finite dimensional real vector spaces. The usual approach is also extremely coordinate-centric and element based.

Many of the problems of affine programming may be described in a more general settings. We may also place a greater emphasis on functions or morphisms in our approach. Here, we describe the questions posed in classical affine programming in as general a setting as possible. We then state several classical affine programming results and describe the hypothesis under which each hold in as great a generality as possible. (Received September 17, 2013)

1096-VM-2254 **Joseph F DiNatale*** (jd4732@stu.armstrong.edu), 101 Royal Oak Court, Savannah, GA 31406. *Electronic Computation of Simple Perfect Squared Squares.*

"Squaring the square" is the problem of dissecting squares of integer side lengths into several smaller squares also of integer side lengths. It is known that an ordinary square may be dissected into at minimum 21 squares. For squares that describe cylinders, the lower bound is 20. To further decrease this lower bound, we consider squares that describe other quotient spaces, including Möbius bands, Klein bottles, and projective planes. We introduce an algorithmic approach for finding such squared squares, extending the results of S.J. Chapman. (Received September 17, 2013)

1096-VM-2386 **Benjamin H DeMeo*** (30howland@gmail.com), **Chaim Goodman-Strauss**, **Matthew Cole** and **Diana Davis**. *Computer Models of Negatively-Curved Surfaces.* Preliminary report.

Using only paper, scissors, and tape, it's easy to construct frameworks for objects that, in theory, should have constant negative curvature. On the other hand, Hilbert's theorem places heavy restrictions on such surfaces. In an attempt to see where Hilbert's theorem fails, we model the behavior of these paper-strip constructions computationally. Only basic familiarity with multivariable calculus is assumed. (Received September 17, 2013)

1096-VM-2527 **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. *On some 3-way transportation polytopes.* Preliminary report.

In this report we are interested in the axial 3-way transportation polytopes that arise as the feasible non-negative integer points of $2 \times 2 \times 2$ contingency tables with given 1-marginals. In particular, we explore the following connection between these (in this case) 4-dimensional polygons and the universal Gröbner basis of the associated constraint matrix A: A relatively prime vector $\boldsymbol{u} \in \ker(A)$ lies in the universal Gröbner basis iff the line segment $[\boldsymbol{u}^+, \boldsymbol{u}^-]$ is an edge of the transportation polytope with vector of marginals $A\boldsymbol{u}^+$ (Theorem 7.8 in "Gröbner Bases and Convex Polytopes" by B. Sturmfels). Preliminary results for 4-way transportation polytopes of $2 \times 2 \times 2 \times 2$ arrays are also presented. (Received September 17, 2013)

1096-VM-2714 **Casey Mann*** (cemann@uw.edu), **Laura Asaro** (laugasar@gmail.com), **John Hyde** (johnny.m.hyde@gmail.com), **Melanie Jensen** (mjensen1@tulane.edu) and **Tyler Schroeder** (tlschroeder@noctrl.edu). *Uniform Edge-c-Colorings of the Archimedean Tilings.* Preliminary report.

A *uniform edge-c-coloring* of an Archimedean tiling is an assignment of colors to the edges of the tiling that is vertex-transitive with respect to color-preserving symmetries of the tiling. The problem of finding all uniform edge-c-colorings for all 11 Archimedean tilings was posed by Grunbaum and Shephard in their book *Tilings and Patterns*. This talk will present the solution to this problem; there are 109 such edge-colored Archimedean tilings. (Received September 18, 2013)

General Session on Research in Graph Theory and Combinatorics

1096-VN-32 **Marilyn Titus*** (mtitusmath@hotmail.com), 202 A Rose Garden Lane, Bentonville, AR. *Finding mono-chromatic K^3 shapes within a complete, unweighted graph with variable c-edge-coloring.* Preliminary report.

Ramsey numbers are a key concept within graph theory. The core question behind Ramsey theory is this: What is the smallest size of complete c-edge-colored graph G that will require a clique of size n? For example, what is the smallest size of graph G that will require a clique of size 3 given that each edge is labelled with one of two colors? The answer is 6 for this example. The broader question remains without a formula. Most work on this question is usually approached by setting two colors and then attempting to determine when a clique of size n of either color would be obtained. This paper explores the other direction, given a set clique size of 3, and a variable amount of colors, when is a mono-chromatic clique of size three required to occur? This paper proves a recursive formula and then uses that recursive formula to give a concrete answer to the question posed above. (Received June 02, 2013)

1096-VN-290 **Nathan Warnberg*** (warnberg@iastate.edu). *Positive Semidefinite Propagation Time.* Preliminary report.

Positive semidefinite (PSD) zero forcing on a simple undirected graph G is based on the following color change rule: Let $B \subseteq V(G)$ be colored black and the rest of the vertices be colored white. Let $C_1, C_2, \ldots, C_k$ be the connected components of $G - B$. For any black vertex b that has exactly one white neighbor w in $G[B \cup C_i]$, change the color of w to black. A minimum PSD zero forcing set (PSDZFS) is a set of black vertices of minimum cardinality that color the entire graph black after iteratively applying the color change rule. The PSD propagation time of a PSDZFS B of graph G is the minimum number of iterations of the color change rule needed to force all vertices of G black, starting with the vertices in B black. Minimum and maximum PSD propagation time are taken over all minimum PSD zero forcing sets. Some interesting results will be presented. (Received August 26, 2013)

1096-VN-442 **Andrew R Gainer-Dewar*** (againerdewar@carleton.edu), Mathematics Department, 1 North College Street, Northfield, MN 55057. *Enumeration of bipartite graphs and blocks.*

Using the theory of combinatorial species, we compute the cycle index series for bipartite graphs, then show how this can be used to enumerate unlabeled bipartite blocks, a problem left open by Robinson in 1979. (Received September 03, 2013)

1096-VN-445 **Elizabeth Lane-Harvard*** (lane@math.colostate.edu) and **Tim Penttila**. *Exploiting Connections Between Graph Theory and Finite Geometry.*

There are many open problems concerning 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 two categories. The methods used involve symmetry and geometry, and experimentation with computer algebra packages to gain insight. (Received September 03, 2013)

1096-VN-565 **Joe DeMaio*** (jdemaio@kennesaw.edu) and **John Jacobson** (jjacob26@students.kennesaw.edu). *The Fibonacci Number of the Tadpole 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 $k \geq 0$. In this talk, we compute $i(T_{n,k})$ and present related identities. (Received September 17, 2013)

1096-VN-571 **Breeann M Flesch*** (fleschb@wou.edu), 345 N Monmouth Ave, Monmouth, OR 97361, and **David E Brown**. *Proper interval p-graphs.* Preliminary report.

Interval p-graphs, introduced in 2002, are the interval graphs in which vertices correspond to intervals of p possible colors and edges correspond to nonempty intersections of differently colored intervals. Interval 2-graphs are traditionally called interval bigraphs and have been studied extensively. However, little work has been done on interval p-graphs when $p > 2$. In this talk we will discuss work that has been done on interval p-graphs with $p > 2$ and give a recent partial characterization for proper interval p-graphs, which are interval p-graphs that can be represented with no interval properly containing another. (Received September 06, 2013)

1096-VN-628 **Bud Brown*** (ezbrown@math.vt.edu), Math Department (0123), 225 Stanger Street, Blacksburg, VA 24061. *Connections between Hamming codes over q-element fields and Singer block designs.*

The first error-correcting codes developed, and the first ones students usually encounter, were efficient ways to detect and correct errors in binary strings by including parity-check bits along with the message bits. Hamming's scheme produced perfect single-error correcting codes – they correct all single-error patterns and only those patterns. Subsequent researchers described such codes for character strings over arbitrary q-element fields, now known as q-ary Hamming codes. We show how to construct such codes, and describe their connections with so-called Singer block designs.

Remember $(q^k - 1)/(q - 1)$, because it's important. (Received September 08, 2013)

1096-VN-635 **Daniel Parry***, Department of Mathematics, 33rd and Market Streets, Philadelphia, PA 19104. *The Pac Man Graph: The Roots of a Class of Partition Polynomials.* Preliminary report.

We consider the polynomials $Q_n(z; s)$ which are the Fourier coefficients of

$$1 + \sum_{n=1}^{\infty} Q_n(z; s) q^n = \prod_{m=1}^{\infty} \frac{1}{(1 - zq^m)^{m^{s-1}}}$$

when $z \in \mathbb{C}$ and $s > 0$. Each Fourier coefficient is a polynomial of degree n and has n roots counting multiplicity. For $s = 1.2$, these polynomials can be viewed as analogues of the integer partition and integer plane partition counting functions and the cases of $s = 1/2, 3/2$, are relevant in specific statistical mechanics models.

We will focus on the study of the roots of $Q_n(z; s)$ for fixed $s > 0$ and as $n \to \infty$. This talk will show that the roots of these polynomials cluster along specific, analytically defined curves in the complex plane which are related to the special function known as the polylogarithm. Time permitting, we will prove asymptotic densities of the roots along each curve. Ultimately, we will demonstrate why we call the limiting sequence of roots of $Q_n(z; s)$, when parameterized by s, the Pack Man graphs. (Received September 08, 2013)

1096-VN-712 **Jon Woltz*** (jwoltz@students.kennesaw.edu), **Matthew Lee Force** (mforce1@students.kennesaw.edu) and **Joe DeMaio** (jdemaio@kennesaw.edu). *Dominating Sets in* $Cay(\mathbb{Z}_n, \{\pm 1, \pm 3, \pm 5, \ldots, \pm(2k-1)\})$.

The circulant graph $Cay(\mathbb{Z}_n, C)$ has as its vertex set the group elements of $\mathbb{Z}_n$ and the $i \to j$ arc exists if and only if $j - i \in C$. If C is closed under inverses then $Cay(\mathbb{Z}_n, C)$ is a graph rather than a digraph. Circulant graphs are a type of Cayley graph. The simplest possible circulant graph is the cycle graph with n vertices, $C_n = Cay(\mathbb{Z}_n, \{\pm 1\})$. It is well known that $\gamma(C_n) = \lceil \frac{n}{3} \rceil$. In 2009, Rad computed $\gamma(Cay(\mathbb{Z}_n, \{\pm 1, \pm 3\})) = \lceil \frac{n}{5} \rceil$ for $n \not\equiv 4 \pmod 5$ and $\lceil \frac{n}{5} \rceil + 1$ for $n \equiv 4 \pmod 5$. In this talk we classify $Cay(\mathbb{Z}_n, \{\pm 1, \pm 3, \pm 5, \ldots, \pm(2k-1)\})$ as either $\lceil \frac{n}{2k+1} \rceil$ or $\lceil \frac{n}{2k+1} \rceil + 1$. (Received September 09, 2013)

1096-VN-714 **Matthew Lee Force*** (mforce1@students.kennesaw.edu), **Jon Woltz** (jwoltz@students.kennesaw.edu) and **Joe DeMaio** (jdemaio@kennesaw.edu). *Cyclic Dominating Sets in Cayley Graphs.*

A set $S \subseteq V$ is a dominating set of a graph $G = (V, E)$ if each vertex in V is either in S or is adjacent to a vertex in S. The domination number of a graph G, $\gamma(G)$, is the minimum cardinality of a dominating set of G. The Cayley digraph, $Cay(G, C)$, for any group G and $C \subseteq G \setminus \{e\}$ has as its vertex set the group elements of G and the $i \to j$ arc exists if and only if $ji^{-1} \in C$. If C is closed under inverses then $Cay(G, C)$ is a graph rather than a digraph. Assume S is a dominating set in $Cay(G, C)$. We call S **cyclic** if there exists $g, h \in G$ such that $S = \{gh^k \mid k = 1, 2, ..., |h|\}$. The cyclic domination number of a graph G, $\gamma_{cy}(G)$, is the minimum cardinality of a cyclic dominating set of G. In this talk we present properties of cyclic dominating sets. (Received September 09, 2013)

1096-VN-782 **Jonathan S Bloom*** (jonathan.bloom@dartmouth.edu), Hanover, NH 03755. *Some Consequences of a New Bijective Proof of the shape-Wilf-equivalence of 231 and 312.*

The concept of shape-Wilf-equivalence, first introduced by Backlin-West-Xin, has been widely studied since its introduction. We say a full rook placement on a fixed Ferrers board F *avoids* a pattern $\sigma \in S_n$ if, for every rectangle that sits inside F, the permutation corresponding to the rooks in this rectangle avoids σ in the usual sense. We then let $R_F(\sigma)$ denote the set of all rook placements on F that avoid σ. Finally, we say that σ is shape-Wilf-equivalent to τ, written $\sigma \sim \tau$, if

$$|R_F(\sigma)| = |R_F(\tau)|$$

for all Ferrers boards F. The proof that $231 \sim 312$, due to Stankova and West, is nonbijective and fairly complicated. We will first demonstrate a new straightforward bijective proof that $231 \sim 312$.

We will then discuss how this bijection can be used to simultaneously give elegant proofs of many existing enumerative results. Most notably among those is the generating function for 1342-avoiding permutations originally due to Bóna. Additionally, this bijection also provides new enumerative results both in pattern avoidance and in the study of perfect matchings and set partitions. (Received September 10, 2013)

1096-VN-799 **John Asplund*** (jsa0011@auburn.edu), **C. A. Rodger** and **Melissa Keranen**. *Enclosings of λ-fold 5-cycle systems.*

A k-cycle system of a multigraph G is an ordered pair (V, C) where V is the vertex set of G and C is a set of k-cycles, the edges of which partition the edges of G. A k-cycle system of λK_v is known as a λ-fold k-cycle system of order v. A k-cycle system of λK_v (V, C) is said to be enclosed in a k-cycle system of $(\lambda + m)K_{v+u}$ $(V \cup U, P)$ if $C \subset P$ and $u, m \geq 1$. In this talk, some methods used to solve the difficult cases when $u = 1$ and 2 will be discussed as well as future work involved with this research. (Received September 10, 2013)

1096-VN-953 **David Blessing*** (dcblessi@eagle.fgcu.edu), 5110 Atlantic Ct., Cape Coral, FL 33901, and **Erik Insko**, **Katie Johnson** and **Christie Mauretour**. *(t,r)-Broadcasting Domination Numbers of Grids.* Preliminary report.

We explore a new domination theory of graphs that we call (t,r)-broadcast domination in the setting of grid graphs. In this theory, a broadcasting vertex v sends a non-negative signal of strength $t-k$ to each vertex that is distance k from v. A (t,r)-dominating set is a subset of broadcasting vertices of a graph G such that every vertex in G receives a combined signal of strength at least r. The theory of (t,r)-broadcast domination has potential applications in real world covering problems such as wide area networking, irrigation, and surveillance. We give minimal (t,r)-domination sets for small grids and prove upper bounds for large grids when $t, r \leq 3$. (Received September 11, 2013)

1096-VN-962 **Kai Orans***, ko002010@mymail.pomona.edu, and **Adam D. King** and **Amanda N. Laubmeier**. *Universal and Overlap Cycles.*

Abstract: A Universal cycle is a string of characters used to represent classes of combinatorial objects in a condensed form. Each object must share $n-1$ characters with adjacent objects and be represented exactly once in the string. Universal cycles are preferred, but sometimes not possible to construct. In these cases, we construct slightly longer, less dense overlap cycles. We show the existence of universal cycles for naturally ordered posets and overlap cycles for juggling patterns in site-swap notation and words of weight k. (Received September 11, 2013)

1096-VN-1019 **Michael D. Barrus*** (barrus@math.byu.edu), Department of Mathematics, Brigham Young University, Provo, UT 84602. *The polytope of fractional realizations of degree sequences.*

We introduce a notion of fractional realizations of a graph degree sequence d and discuss the convex polytope $P(d)$ formed by points associated with these realizations. Simple graph realizations correspond to extreme points of $P(d)$, though for a typical d the extreme points include other fractional realizations as well. We characterize the extreme points of the polytope and characterize the degree degree sequences d for which the extreme points of $P(d)$ correspond exactly to simple graph realizations. We characterize the graphs having such degree sequences and show how their structure generalizes that of the pseudo-split graphs. (Received September 12, 2013)

1096-VN-1072 **Justin R. Hughes*** (hughes@math.colostate.edu), Colorado State University, Department of Mathematics, 101 Weber Building, Fort Collins, CO 80523. *Representations Arising from an Action on D-neighborhoods of Cayley Graphs.*

Given G a finite group and a generating set, one can construct the Cayley Graph. With a set D comprised of nonnegative integers one can construct a D-neighborhood complex from the Cayley Graph. This neighborhood complex is a simplicial complex and thus it is natural to form an associated chain complex. The group G acts naturally on the chain complex and this leads to an action on the homology of the chain complex. These group actions give rise to several representations of G. This work uses tools from group theory, representation theory and homological algebra to further our understanding of the interplay between generated groups (i.e. a group together with a set of generators), corresponding representations on their associated D-neighborhood complexes, and the homology of the D-neighborhood complexes. (Received September 12, 2013)

1096-VN-1132 **Brad Bailey***, UNG Department of Mathematics, 82 College Circle, Dahlonega, GA 30597, and **Dianna J. Spence**, UNG Department of Mathematics, 82 College Circle, Dahlonega, GA 30597. *Path Elongation of Graphs.* Preliminary report.

For a graph G with cutting number 1, we define the term path-elongation as follows. First, let C be a cycle in G and let u and v be vertices of G. Next, let $G \setminus C$ refer to the subgraph of G that results from removing only the edges of C. Then $pe(u, v, C, G) = \text{dist}(u, v, G \setminus C) - \text{dist}(u, v, G)$ and then $pe(u, v, G) = \max\{pe(u, v, C, G) :$ C is a cycle of $G\}$. In words, how much longer is the shortest path from u to v after C is removed? Finally, $pe(G) = \max\{pe(u, v, G) : u, v \in G\}$.

In this talk, we establish the path elongations for graphs with certain structures. We also show that path elongation is not bounded. We also respond to the following question: Can a single graph G have pairs of vertices (u_i, v_i) so that $pe(u_i, v_i, G) = i$ for each $i = 0, \ldots, k$ for any k? (Received September 13, 2013)

1096-VN-1139 **Derege H Mussa*** (/derege.mussa@tamuc.edu/dhm2114@columbia.edu), Department of Mathematics, Texas A&M University-Commerce, Commerce, TX 75429. *Reconstruction of Tetrahedron from Edge length.* Preliminary report.

Abstract If one has three sticks (length), when you make a triangle with the sticks? As long as any two of the lengths sum to a value strictly larger than the third length one can make a triangle. 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. Perhaps surprisingly , if one is given 6 sticks (length) there is no simple way of telling if one can build a tetrahedron with the sticks .In fact, even though one can make a triangle with any triple of three lengths selected from the six, one still may not be able to build a tetrahedron. At the other extreme, if one can make a tetrahedron with the six lengths, there are at most 30 different (incongruent) tetrahedra with the six distinct edge lengths and each tetrahedron is congruent with 24 tetrahedra corresponding to the 24 ways of labeling the four vertices for a total of 720 tetrahedra . The paper discus new mathematical questions: 1. How to reconstruct incongruent tetrahedra from the six edge lengths 2. What is the maximum number of incongruent tetrahedron with six edge lengths can be formed (Received September 13, 2013)

1096-VN-1159 **Naiomi T. Cameron*** (ncameron@lclark.edu), Department of Mathematical Sciences, Lewis & Clark College, 0615 SW Palatine Hill Road, Portland, OR 97219. *Generalized Fine and Motzkin Number Sequences.* Preliminary report.

In this talk, I will describe a generalization of each of the Fine and Motzkin numbers and point out some connections between them. A generalized t-Dyck path is a path from $(0,0)$ to $((t+1)n,0)$ using up and down steps of the form $U(1,1)$ and $D(1,-t)$ and never going below the x-axis. The generalized Fine sequence counts generalized t-Dyck paths with no hills, where a hill is defined as a ground level subpath of length $t+1$ and form $UU\cdots UD$. (Note that this is different than counting t-Dyck paths having no peaks of minimal height.) I will present a generalization of the nonobvious identity

$$(2z+z^2)F^2(z)-(1+2z)F(z)+1=0,$$

where $F(z)$ is the generating function for Fine numbers, indicating how this generalization can be used to compute the asymptotic proportion of t-Dyck paths having a given number of hills. The generalization of the Motzkin number sequence will be obtained by adding t steps of the form $(1,0)$, $(1,-1)$, $(1,-2)$, …, $(1,-t+1)$ to the step set of t-Dyck paths. I will describe a coloring of these modified paths which retrieves the generalized Catalan numbers and I will discuss subsets of these generalized Motzkin paths which are enumerated by the generalized Fine sequence. (Received September 13, 2013)

1096-VN-1216 **Ralph P. Grimaldi*** (grimaldi@rose-hulman.edu), Mathematics Department, RHIT, 5500 Wabash Avenue, Terre Haute, IN 47803. *Odd-Neighbored Subsets.*

For $n \geq 1$, a subset S of $[n]=\{1,2,3,\dots,n\}$ is called *odd-neighbored* if for each even integer $k \in S, k-1 \in S$, and if $k+1 \leq n$, then $k+1 \in S$. When $n=4$, for example, we find eight such subsets - namely, $\emptyset$, $\{1\}$, $\{3\}$, $\{1,3\}$, $\{1,2,3\}$, $\{3,4\}$, $\{1,3,4\}$, and, $\{1,2,3,4\}$. In general, there are F_{n+2} odd-neighbored subsets of $[n]$, where F_n denotes the nth Fibonacci number.

Formulas for the following are derived for these types of subsets: 1) the total number of elements that appear, as well as the numbers of odd and even elements; 2) the sum of all the elements that appear, as well as the sums for the odd and even elements; and, 3) the number of strings of consecutive integers in these odd-neighbored subsets. (Received September 13, 2013)

1096-VN-1473 **Samuel Connolly*** (samuelc@sas.upenn.edu), **Zachary Gabor** (zgabor@haverford.edu), **Anant Godbole** and **Bill Kay**. *Bounds on the Maximum Number of Minimum Dominating Sets.*

We use probabilistic methods to find lower bounds on the maximum number, in a graph with domination number γ, of dominating sets of size γ. We find that we can randomly generate a graph that, w.h.p. is dominated by almost all sets of size γ. At the same time, we use a modified version of the adjacency matrix to obtain lower bounds on the number of sets of a given size that do not dominate a graph on n vertices. (Received September 16, 2013)

1096-VN-1656 **Zachary George Pochiba*** (pochibazg@washjeff.edu), Mathematics Department, 60 South Lincoln Street, Washington, PA 15301, and **Sean Leavor**. *Aperiodic Binary Strings.*

There are 2^n possible binary strings. These strings can be either periodic, which contain repeating substrings, or aperiodic, which do not. Let a_n represent the number of aperiodic strings of length n. We showed that the number of periodic strings of length n is equal to $\sum\limits_{d|n,\ d<n} a_d$ so that a_n is given by the recursive formula $a_n = 2^n - \sum\limits_{d|n,\ d<n} a_d$. We also proved that for $n>2$, a_n is divisible by 6, and that as n approaches infinity, the ratio of adjacent terms $\frac{a_{n+1}}{a_n}$ approaches 2. We then derived explicit formulas for a_n for specific cases of n, such as prime numbers, power of primes, and product of distinct primes. We also extended the idea to strings that contain more than two symbols. (Received September 16, 2013)

1096-VN-1731 **Stephen M. Adams*** (smadams2@ncsu.edu), North Carolina State University, Department of Mathematics, Campus Box 8205, Raleigh, NC 27695. *On Distributive Cross Section Lattices of $\mathcal{J}$-irreducible Reductive Monoids.* 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 case the cross section lattice is completely determined by the type of the minimal element and the Coxeter-Dynkin diagram of G. In this talk we will provide some combinatorial properties of distributive cross section lattices of $\mathcal{J}$-irreducible monoids. (Received September 16, 2013)

1096-VN-1746 **Charles Suer*** (suerchaj@gmail.com), University of Louisville, Department of Mathematics, 328 Natural Sciences Bldg, Louisville, KY 40292-0001. *Extending the PC-Tree Algorithm to the Torus.* 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. As a proof-of-concept, we show how to accomplish this for $K_{3,3}$-free graphs. If time permits, the general toroidality checking algorithm will also be considered. (Received September 16, 2013)

1096-VN-1803 **Francesca Romano*** (fm20roma@siena.edu), 946 Kings Rd, Schenectady, NY 12303. *Explicit Formulas for Bernoulli and Euler Numbers.* Preliminary report.

By directly considering Taylor coefficients and composite generating functions, we employ a generalized Faá di Bruno formula for higher partial derivatives using vector partitions to obtain identities that include explicit formulas for the Bernoulli and Euler numbers. (Received September 16, 2013)

1096-VN-1842 **Daniel Gray*** (dgray1@ufl.edu). *Bounds on superpatterns containing all layered permutations.* Preliminary report.

In the study of pattern containment, a k-superpattern is a permutation which contains all $k!$ permutations of length k as a pattern. One may also consider restricted superpatterns, i.e. a permutation which contains, as a pattern, every element in some subclass of the set of permutations of length k. Here, we find lower and upper bounds on a superpattern which contains all layered k-permutations. Also, we exhibit a connection between the sum of depths of null-balanced binary trees on k vertices. (Received September 16, 2013)

1096-VN-1856 **Samuel Connolly**, **Zachary Gabor*** (zgabor@haverford.edu) and **Anant Godbole**. *Location of the First Ascent in a 123-Avoiding Permutation.*

It is natural to ask, given a permutation with no three-term ascending subsequence,at what index the first ascent occurs. We show, using both a recursion and a bijection, that the number of 123-avoiding permutations at which the first ascent occurs at positions j, $j+1$ is given by the j-fold Catalan convolution. Two interesting discrete probability distributions, related obliquely to the Poisson and geometric random variables, are derived as a result. (Received September 16, 2013)

1096-VN-1857 **Tilahun A Muche*** (muchet@savannahstate.edu), 3219 College Street, Savannah State University, Mathematics and Statistics Dept., Savannah, GA 31404. *Assembly Number and Loop Saturated Graphs.* Preliminary report.

Graphs with 4 valent rigid vertices and two end points are called assembly graphs. The *assembly number* of Γ, denoted by $An(\Gamma)$, is defined by $An(\Gamma) = \min\{\ k \mid$ there exists a Hamiltonian set of polygonal paths $\{\gamma_1, \dots, \gamma_k\}$ in $\Gamma\}$ where polygonal paths are paths that take "$90°$ *turn*" at each vertex. For a positive integer n, we define *minimal realization number for* n to be $R_{\min}(n) = \min\{|\Gamma| : An(\Gamma) = n\}$. For a positive integer n,a graph Γ such that $R_{\min}(n) = |\Gamma|$ is called minimal realization graph. We denote by $\mathcal{R}_{\min}(n)$,the set of minimal realization graphs for some positive integer n. Each $\Gamma\in \mathcal{R}_{\min}(n)$ has the property that $|\Gamma| \leq 3n-2$ and $R_{\min}(n)<R_{\min}(n+1)$ for every natural number n. The assembly graph $\hat{\Gamma}^o$ obtained from a given assembly graphΓ by substituting every edge with a loop 11, is called *loop-saturated graph.* We prove that loop saturated assembly graphs achieve the bound of $3n-2$ and if a simple assembly graph Γ with $An(\Gamma){=}k$ has no loops then it is not in $\mathcal{R}_{\min}(k)$. (Received September 16, 2013)

1096-VN-1882 **Mitch A Phillipson*** (phillipson@math.tamu.edu) and **Catherine Yan**. *Non-restricted fillings of layer polynominoes.*

Over unrestricted fillings of moon polyominoes counter examples show that the distribution of northeast and southeast chains is not symmetric. However it is true that $\mathrm{Av}(\mathrm{ne}_k) = \mathrm{Av}(\mathrm{se}_k)$, or the number of fillings that avoid a northeast k-chain is the same as avoid a southeast k-chain. Over general polyominoes - convex but not intersection–free - there is no symmetry of the joint distribution and $\mathrm{Av}(\mathrm{ne}_2) \neq \mathrm{Av}(\mathrm{se}_2)$. Our work deals with layer polyominoes - intersection–free and row–convex. We've shown that for restricted fillings of layer polyominoes the joint distribution is symmetric and for unrestricted fillings $\mathrm{Av}(\mathrm{ne}_2) = \mathrm{Av}(\mathrm{se}_2)$. We will describe two new bijections to demonstrate these. (Received September 16, 2013)

1096-VN-1964 **Lisa Kaylor**, Wesleyan University, Middletown, CT 06459, and **David Offner***, Westminster College, New Wilmington, PA 16172. *Counting Matrices Over a Finite Field With All Eigenvalues in the Field.*

Given a finite field $\mathbb{F}$ and a positive integer n, we give a procedure to count the $n \times n$ matrices with entries in $\mathbb{F}$ with all eigenvalues in the field. We give an exact value for any field for values of n up to 4, and prove that for fixed n, as the size of the field increases, the proportion of matrices with all eigenvalues in the field approaches $1/n!$. The proofs of these results rely on the fact that any matrix with all eigenvalues in $\mathbb{F}$ is similar to a matrix in Jordan canonical form, and so we proceed by counting the number of $n \times n$ Jordan forms, and how many matrices are similar to each one. A key step in the calculation is to characterize the matrices that commute with a given Jordan form and count how many of them are invertible. (Received September 16, 2013)

1096-VN-2088 **Timothy B. Flowers** and **Shannon R. Lockard*** (slockard@bridgew.edu). *Observations of $m-$ary partitions on an $m-$ary tree.* Preliminary report.

In 1999, Neil Calkin and Herb Wilf introduced the Calkin-Wilf tree and discussed its connection to the hyperbinary partition function. Since that time, several papers have examined this binary tree and its connection to the Stern-Brocot sequence. Others have given generalizations of the tree and studied a more general class of partitions, called hyper $m-$ary partitions. In this talk we introduce an $m-$ary tree that is a generalization of the Calkin-Wilf tree. We will discuss characteristics of this tree and show how the tree reveals several properties of hyper $m-$ary partitions. (Received September 17, 2013)

1096-VN-2225 **Brian G. Kronenthal*** (kronenthal@kutztown.edu). *Graphs defined by systems of equations.*

Let G be a bipartite graph with partite sets labeled P and L. Furthermore, let $\mathbb{F}$ be a field, and $n \geq 2$ be an integer. Label every vertex in P with a unique element of $\mathbb{F}^n$. Do the same for L. Then G is *defined by a system of equations*, or alternatively is called an *algebraically defined graph*, if there exist $n-1$ bivariate functions $f_i : \mathbb{F}^2 \to \mathbb{F}$ such that a vertex $(a_1, \ldots, a_n)$ in P is adjacent to a vertex $[x_1, \ldots, x_n]$ in L if and only if $a_i + x_i = f_i(a_1, x_1)$ for all $i = 2, \ldots, n$.

In this talk, we will explain how such graphs can be used to study certain problems in extremal combinatorics. In particular, we will discuss results related to the construction of new generalized quadrangles of odd order. (Received September 17, 2013)

1096-VN-2235 **Feryal Alayont*** (alayontf@gvsu.edu), GVSU Mathematics Department, 1 Campus Dr., Allendale, MI 49401. *A new combinatorial interpretation of generalized Genocchi numbers.*

The classical rook theory can be generalized to three and higher dimensions by letting rooks attack along hyperplanes. With this generalization, it is possible to find a family of three and higher dimensional boards whose maximum rook numbers correspond to generalized Genocchi numbers. From this rook theory perspective, it follows that generalized Genocchi numbers count permutation-tuples with certain conditions. (Received September 17, 2013)

1096-VN-2238 **Aydin Gerek*** (ayg207@lehigh.edu) and **Garth T. Isaak** (gi02@lehigh.edu). *Hamiltonian Ptolemaic Graphs are Cycle Extendable.*

A cycle is extendable if there exists another cycle on the same set of vertices plus one more vertex. G.R.T. Hendry conjectured (1990) that every non spanning cycle in a Hamiltonian chordal graph is extendable. This has been shown to be true for some subclasses of chordal graphs including planar chordal graphs (2002), interval graphs, strongly chordal graphs with (two specific) forbidden subgraphs, split graphs (2006), and spider intersection graphs (2013). We verify it for Ptolemaic graphs. (Received September 17, 2013)

1096-VN-2364 **Andrew Lazowski*** (lazowskia@sacredheart.edu), 5151 Park Ave., Fairfield, CT 06825. *Finite Factors and Graph Labelings.*

In 1996 Albertson and Collins defined distinguishing labelings of undirected graphs. Such labelings have been since applied to directed graphs. Here we consider a directed graph G associated to the k-block presentation of a Bernoulli scheme X. A labeling of G defines a finite factor f of X. We will discuss implications concerning the finite factor of X being finitarily Markovian with respect to properties of f. Namely we are interested in cases where f is r-demarcating or r-distinguishing. (Received September 17, 2013)

1096-VN-2402 **Emily Marie Walther*** (waltem22@wclive.westminster.edu), Westminster College Box 472, 319 South Market Street, New Wilmington, PA 16172, and **Ariana Cappon**. *Prime Factorization of Kászonyi Numbers.*

Snarks are a class of simple, cubic, non-planar graphs that cannot be edge-3-colored. By a result of Kászonyi, if G is a snark, e is an edge of G, and G_e is the cubic graph that one obtains by deleting the edge e and "eliminating" its endpoint vertices, then the number of edge-3-colorings of G_e with three given colors will be $18 \cdot \psi(G, e)$ for some nonnegative integer $\psi(G, e)$. It has been previously shown that there exists a cyclically 4-edge connected snark G_0 with and edge g_0 such that $\psi(G_0, g_0) = 2^a \cdot 3^b \cdot 5^c \cdot 7^d$ where a, b, c, and d are arbitrary non-negative integers. In this talk, we will show that for every positive integer n where prime factors of n are all less than or equal to 149, there exists a snark G and an edge e of G such that $\psi(G, e) = n$. (Received September 17, 2013)

1096-VN-2407 **Zachary Hamaker*** (zachary.hamaker@gmail.com), 3 School St. Apt B, Hanover, NH 03755, and **Benjamin Young** (bjy@uoregon.edu), Department of Mathematics, 1222 University of Oregon, Eugene, OR 97403-1205. *Edelman-Greene insertion and the Little map.*

The Little map and the Edelman-Greene insertion algorithm, a generalization of the Robinson-Schensted correspondence, are both used for enumerating the reduced decompositions of an element of the symmetric group. We show the Little map factors through Edelman-Greene insertion and establish new results about each map as a consequence. In particular, we resolve some conjectures of Lam and Little. (Received September 17, 2013)

1096-VN-2434 **Avinash J. Dalal*** (adalal@math.drexel.edu), Department of Mathematics, Korman Center 206, 33rd and Market Streets, Philadelphia, PA 19104. *On atom expansions of Macdonald polynomials.* Preliminary report.

A long-standing open problem is to find a combinatorial interpretation for the coefficients in the Schur expansion for Macdonald polynomials

$$H_\mu[X; q, t] = \sum_\lambda K_{\lambda\mu}(q, t) s_\lambda.$$

The Kostka-Foulkes polynomials, $K_{\lambda\mu}(0, t)$, appear in many contexts such as Hall-Littlewood polynomials, affine tensor product multiplicities and they encode dimensions of certain bigraded S_n-modules.

In their study of Macdonald polynomials, Lapointe, Lascoux and Morse found computational evidence for a family of new bases $\{A_\mu^{(k)}(x; t)\}_{\mu_1 \leq k}$ for subspaces of the ring of symmetric functions. Most relevant to the work was the empirical study of $\{A_\mu^{(k)}(x; t)\}_{\mu_1 \leq k}$ leading ties to representation theory and conjectures that affine Schubert calculus is strongly linked to the theory of Macdonald polynomials.

To this end, we introduce one parameter families of symmetric functions that transition positively with Hall-Littlewood and Macdonald's P-functions and specialize to certain Schubert representatives in affine Schubert calculus. Our work relies on a notion of translation that presents a surprising connection between chains in the strong and weak order poset on the affine Weyl group $\tilde{A}_{n-1}$. (Received September 17, 2013)

1096-VN-2547 **Jae-Ho Lee*** (jhlee@math.wisc.edu), 480 Lincoln Dr., Madison, WI 53706. *The generalized Terwilliger algebra of a distance-regular graph and a double affine Hecke algebra.*

Let Γ denote a Q-polynomial distance-regular graph with vertex set X. We assume that Γ contains a Delsarte clique C. Fix a vertex $x \in C$. We introduce the generalized Terwilliger algebra $\mathbf{T} = \mathbf{T}(x, C)$ which is the subalgebra of $Mat_X(\mathbb{C})$ generated by the Terwilliger algebras $T = T(x)$ and $\widetilde{T} = \widetilde{T}(C)$. Using C we construct an irreducible $\mathbf{T}$-module $\mathbf{W}$. The universal double affine Hecke algebra of type $(C_1^\vee, C_1)$ is the $\mathbb{C}$-algebra $\hat{H}_q$ defined by generators $\{t_n^{\pm 1}\}_{n=0}^3$ and relations (i) $t_n t_n^{-1} = t_n^{-1} t_n = 1$; (ii) $t_n + t_n^{-1}$ is central; (iii) $t_0 t_1 t_2 t_3 = q^{-1/2}$. We turn the $\mathbf{T}$-module $\mathbf{W}$ into an $\hat{H}_q$-module and discuss how the actions of $\mathbf{T}$ and $\hat{H}_q$ on $\mathbf{W}$ are related. (Received September 17, 2013)

1096-VN-2613 **Matthew Moynihan*** (mmoynihan@wooster.edu). *The Flag Descent Algebra.* Preliminary report.

We examine signed permutations and show that the type A Eulerian descent algebra is a two-sided ideal in the algebra spanned by the basis elements from the type A and type B Eulerian descent algebras. This larger algebra corresponds to the flag descent number of Adin, Brenti, and Roichman and so is called the flag descent algebra. We end by describing a set of orthogonal idempotents which span this algebra. (Received September 17, 2013)

1096-VN-2630 **Ellen K Sparks*** (esparks89@att.net), Department of Mathematics, St. Anne Community High School, 650 W Guertin St, St. Anne, IL 60964, and **Adriana Arias**, **Ryan C. Bunge**, **Maira Carmona Herrera**, **Saad I El-Zanati** and **Uthoomporn Jongthawonwuth**. *On cyclic decompositions of $K_{n-1,n-1}+I$ into a 2-regular graph with at most 2 components.*

Let G with n edges be a 2-regular bipartite graph with one or two components. We show that there exists a cyclic G-decomposition of the complete bipartite graph $K_{n-1,n-1}+I$, where I is a 1-factor. (Received September 17, 2013)

1096-VN-2647 **Natacha C. Fontes-Merz*** (fontesnc@westminster.edu), **Jeffrey Boerner** and **James Anthony**. *More Results on Harmoniously Critical Graphs.* Preliminary report.

A harmonious coloring of a graph is a proper vertex coloring in which each pair of colors appear on at most one pair of adjacent vertices. The minimum number of colors needed to harmoniously color a graph G is called the harmonious chromatic number of G. In this talk we will continue to determine classes of graphs which have the property that the removal of any edge reduces the harmonious chromatic number. (Received September 17, 2013)

1096-VN-2677 **Janet L. Fierson*** (fierson@lasalle.edu), Dept. of Mathematics and Computer Science, La Salle University, 1900 W. Olney Ave., Philadelphia, PA 19141, and **Katherine Boligitz**. *Distinguished-color rainbow connection in graphs.* Preliminary report.

In an edge-colored graph G, a path is said to be a rainbow path if no two of its edges share a color. The rainbow connection number of a connected graph G, denoted by $rc(G)$, is the minimum number of colors needed to color the edges of G in such a way that there exists at least one rainbow path between every pair of vertices.

We introduce an additional condition involving a distinguished color. It is not always possible to satisfy both this new condition and rainbow connectedness with just $rc(G)$ colors; this leads to the definition of the distinguished-color rainbow connection number of a graph G, denoted by $drc(G)$. We present results for $drc(G)$ for several specific classes of graphs and look at general relationships between $drc(G)$ and $rc(G)$. We also investigate related questions involving path length. (Received September 17, 2013)

1096-VN-2680 **K. Bragan***, Parker 221, Auburn University, Auburn, AL 36849, and **J. Hammer**, **P. Johnson** and **K. Roblee**. *On the Existence and Structure of Edge-Regular Graphs.*

An edge-regular graph is a regular graph in which, for some λ, any two adjacent vertices have exactly λ common neighbors. We consider the existence and structure of members of certain classes of edge-regular graphs. (Received September 17, 2013)

General Session on Research in Number Theory

1096-VO-21 **Keneth Adrian Precillas Dagal*** (kendee2012@gmail.com), Lot 15, Blk 30, Urban Poor, Pacol, 4400 Naga, Camarines, Philippines. *Generalized Locker Problem.*

The Locker Problem is frequently used in introducing some topics in elementary number theory like divisors and multiples. It appears in many curricula ranging from elementary, secondary and up to tertiary level. In this paper, I will provide the structure of the problem and algorithms in solving some modified problems.

The locker problem varies in terms of the number of lockers and students. But the number of lockers and students is assumed to be equal.In most cases, the number is 100, but there are cases wherein the number is 20 or 1000. The answer is known that those lockers whose number is a perfect square will be left opened.

In this paper, we consider the possibility that the number of students and the number of lockers is unequal. We also consider the possibility of students repeating turns and the possibility that some students will not participate in the activity.But we preserve the rule of the problem which is every ith student will change the state of all lockers numbered j where $i \mid j$. In addition to this, I will provide algorithms in finding the corresponding open or close lockers given a subset of students and vice versa. (Received May 21, 2013)

1096-VO-49 **Jay L. Schiffman*** (schiffman@rowan.edu), 201 Mullica Hill Road, Glassboro, NJ 08028-1701. *A Delightful Interconnection Encompassing Pythagorean Triples, Algebra, Geometry and Modular Arithmetic.* Preliminary report.

This paper will embark on a study of Pythagorean triples as they relate to the areas and perimeters of right triangles. For example, one can easily demonstrate a method to obtain right triangles whose areas are integer multiples of their respective perimeters. In addition, the role played by modular arithnmetic in achieving our goal will be emphasized via easily posed conjectures that are based on the table of Pythagorean triples. Easily understandable proofs will be furnished in a setting that only requires a level of mathematical maturity that is obtained in elementary collegiate mathematics. (Received June 15, 2013)

1096-VO-255 **Umang Varma*** (umang.varma10@kzoo.edu), 1200 Academy St, Kalamazoo, MI 49006, and **Philippe Demontigny**, **Thao Do**, **Archit Kulkarni**, **Steven J Miller** and **David Moon**. *Generalizing Zeckendorf's Theorem to f-decompositions.*

A beautiful theorem of Zeckendorf states that every positive integer can be uniquely expressed as a sum of non-consecutive Fibonacci numbers. For sequences $\{G_n\}$ satisfying linear recurrence relations with nonnegative coefficients, there is a notion of a legal decomposition which again leads to a unique representation. The number of summands in the representations of $m \in [G_n, G_{n+1})$ converges to a Gaussian as $n \to \infty$.

Given a notion of legal decomposition, we ask if there exists a sequence $\{a_n\}$ such that every positive integer can be uniquely decomposed as a sum of terms from $\{a_n\}$. Let $f : \mathbb{N}_0 \to \mathbb{N}_0$. We say that if a_n is in an "f-decomposition" of a number x, then the decomposition cannot contain the $f(n)$ terms immediately before a_n in the sequence. We prove that for any $f : \mathbb{N}_0 \to \mathbb{N}_0$, there exists a sequence $\{a_n\}$ such that every positive integer has a unique f-decomposition using $\{a_n\}$. If f is periodic, then the unique increasing sequence $\{a_n\}$ induced by f satisfies a linear recurrence relation. For some class of functions f, we prove that the number of summands in the f-decomposition of integers in a suitable growing interval converges to a normal distribution. (Received August 23, 2013)

1096-VO-271 **Jose A. Velez-Marulanda***, Department of Mathematics & Computer Science, 2072 Nevins Hall, 1500 N. Patterson St., Valdosta, GA 31602. *On the infinitude of prime elements.*

Let R be an infinite unique factorization domain with at most finitely many units. We discuss the infinitude of prime elements in R when R is arbitrary and when R satisfies the following property: if f and g are polynomials with coefficients in R such that $f(r)$ divides $g(r)$ for all $r \in R$ with $f(r) \neq 0$, then either $g = 0$ or $\deg f \leq \deg g$. (Received August 25, 2013)

1096-VO-368 **Lorin Crawford**, **Vadim Ponomarenko*** (vponomarenko@mail.sdsu.edu), **Jason Steinberg** and **Marla Williams**. *Accepted Elasticity in Local Arithmetic Congruence Monoids.*

For certain $a, b \in \mathbb{N}$, an *Arithmetic Congruence Monoid* $M(a, b)$ is a multiplicatively closed subset of $\mathbb{N}$ given by $\{x \in \mathbb{N} : x \equiv a \pmod b\} \cup \{1\}$. An *irreducible* in this monoid is any element that cannot be factored into two elements, each greater than 1. Each monoid element (apart from 1) may be factored into irreducibles in at least one way. The *elasticity of a monoid element* (apart from 1) is the longest length of a factorization into irreducibles, divided by the shortest length of a factorization into irreducibles. The *elasticity of the monoid* is the supremum of the elasticities of the monoid elements. A monoid has *accepted elasticity* if there is some monoid element that has the same elasticity as the monoid. An Arithmetic Congruence Monoid is *local* if $\gcd(a, b)$ is a prime power (apart from 1). It has already been determined whether Arithmetic Congruence Monoids have accepted elasticity in the non-local case; we make make significant progress in the local case, i.e. for many values of a, b. (Received August 30, 2013)

1096-VO-564 **Joshua Harrington*** (jsharrington@ship.edu), Department of Mathematics, 1871 Old Main Drive, Shippensburg, PA 17257, **Lenny Jones** (lkjone@ship.edu), Department of Mathematics, 1871 Old Main Drive, Shippensburg, PA 17257, and **Daniel White** (dwhite@ship.edu), Department of Mathematics, 1871 Old Main Drive, Shippensburg, PA 17257. *The Reducibility of Constant-Perturbed Products of Cyclotomic Polynomials.*

In 1906, Schur raised the question of the irreducibility over $\mathbb{Q}$ of polynomials of the form $f(x) = (x - a_1)(x - a_2) \cdots (x - a_n) + 1$, where the a_j are distinct integers. In this talk, we investigate the analogous question when replacing the linear polynomials with cyclotomic polynomials and allowing the constant perturbation of the product to be any integer $d \notin \{-1, 0\}$. (Received September 06, 2013)

1096-VO-1069 **Marc Chamberland*** (chamberl@math.grinnell.edu). *Averaging Structure in the $3x + 1$ Problem.* Preliminary report.

The famous 3x+1 problem has resisted analysis from multiple perspectives for many decades. This talk studies the more general $qx + r$ problem, where q and r are odd, and finds new, averaging structures for the iterates. This structure supports the conjecture that all orbits enter a cycle if $q = 1$ or 3 but most orbits diverge if $q \geq 5$. (Received September 12, 2013)

1096-VO-1255 **Spencer Hamblen*** (shamblen@mcdaniel.edu), **Rafe Jones** and **Kalyani Madhu**. *Primes in Orbits of $z^d + c$.*

Given a polynomial $f(z) = z^d + c$ and an element a of a global field K, we will examine the density of prime ideals dividing an element of the orbit of a under f. If K contains a primitive d-th root of unity, we show that for many choices of c, this density is zero for all a. The proof involves new results on bounding the number of irreducible factors of f^n and the ramification of primes in iterated extensions of K. (Received September 14, 2013)

1096-VO-1324 **Nikolai A Krylov*** (nkrylov@siena.edu), Siena College, 515 Loudon Road, Loudonville, NY 12211. *A basis of the group of primitive almost pythagorean triples.*

Let m be a fixed square-free positive integer, then equivalence classes of solutions of Diophantine equation $x^2 + m \cdot y^2 = z^2$ form an infinitely generated abelian group under the operation induced by the complex multiplication. In this talk I will describe a basis of this group in terms of the prime ideals and the ideal class group of the imaginary quadratic field $\mathbb{Q}(\sqrt{-m})$. (Received September 14, 2013)

1096-VO-1367 **Robert G. Underwood*** (runderwo@aum.edu), Auburn University Montgomery, Department of Mathematics, P.O. Box 244023, Montgomery, AL 36124. *On the Content Bound for Real Quadratic Field Extensions.*

Let K be a finite extension of $\mathbb{Q}$ and let $S = \{\nu\}$ denote the collection of normalized absolute values on K. Let V_K^+ denote the additive group of adeles over K and let $\mathbf{c} : V_K^+ \to \mathbb{R}_{\geq 0}$ denote the content map defined as $\mathbf{c}(\{a_\nu\}) = \prod_{\nu \in S} \nu(a_\nu)$ for $\{a_\nu\} \in V_K^+$. A classical result of J. W. S. Cassels states that there is a constant $c > 0$ depending only on the field K with the following property: if $\{a_\nu\} \in V_K^+$ with $\mathbf{c}(\{a_\nu\}) > c$, then there exists a non-zero element $b \in K$ for which $\nu(b) \leq \nu(a_\nu)$, $\forall \nu \in S$. Let c_K be the greatest lower bound of the set of all c that satisfy this property. In the case that K is a real quadratic extension there is a known upper bound for c_K due to S. Lang. The purpose of this paper is to construct a new upper bound for c_K in the case that K has class number one. We compare our new bound with Lang's bound for various real quadratic extensions and find that our new bound is better than Lang's in many instances. (Received September 15, 2013)

1096-VO-1548 **Alan Chang*** (acsix@math.princeton.edu), Department of Mathematics, Fine Hall, Washington Road, Princeton, NJ 08544, and **Steven J Miller** (steven.j.miller@williams.edu) and **Julio Andrade** (julio_cesar_bueno_de-andrade@brown.edu). *Newman's Conjecture in Various Settings.*

Polya introduced a deformation of the Riemann zeta function $\zeta(s)$, and De Bruijn and Newman found a real constant Λ which encodes the movement of the zeros of $\zeta(s)$ under the deformation. The Riemann hypothesis is equivalent to $\Lambda \leq 0$. Newman made the conjecture that $\Lambda \geq 0$ along with the remark that "the new conjecture is a quantitative version of the dictum that the Riemann hypothesis, if true, is only barely so."

Newman's conjecture is still unsolved, and previous work could only handle the Riemann zeta function and quadratic Dirichlet L-functions, obtaining lower bounds very close to zero (for example, for $\zeta(s)$ the bound is at least $-1.14541 \cdot 10^{-11}$). We generalize the techniques to apply to a wider class of L-functions, including automorphic L-functions as well as function field L-functions.

Each type of "family" of function field quadratic L-functions gives a different version of Newman's conjecture. These variations have connections to other fields, including random matrix theory and the Sato–Tate conjecture. In particular, the recent proof of Sato–Tate for elliptic curves over totally real fields allows us to prove a version of Newman's conjecture involving fixed $D \in \mathbb{Z}[T]$ of degree 3. (Received September 16, 2013)

1096-VO-1877 **Timothy James All*** (all1@rose-hulman.edu). *On p-adic annihilators of real ray classes.*

Let k_n be the cyclotomic extension over $\mathbb{Q}$ of conductor n. A classical theorem of Stickelberger states that explicit elements of the Galois group ring $\mathbb{Z}[Gal(k_n/\mathbb{Q})]$ annihilate the the ideal class group of k_n. Sinnott generalized this theorem to the abelian number field case, and Schmidt further generalized this theorem so as to derive explicit annihilators of the ray class groups of an abelian number field, say k. Unfortunately, if k is real, these annihilators all regress into trivial elements, i.e., multiples of the norm. In this paper, we address the real case. To be precise, let k be a real abelian number field, and let $\mathfrak{o}$ be the ring of integers of the topological closure of k embedded into the algebraic closure of $\mathbb{Q}_p$ where p is an odd prime. Let A be the Sylow p-subgroup of a ray class group of k. In this paper, we derive explicit non-trivial elements in $\mathfrak{o}[Gal(k/\mathbb{Q})]$ that annihilate $A \otimes_{\mathbb{Z}} \mathfrak{o}$. (Received September 16, 2013)

1096-VO-1903 **Philippe Demontigny*** (ppd1@williams.edu), 5 Litton Road, Flemington, NJ 08822, and **Thao T Do** and **Steven J. Miller**. *A Generalization of Fibonacci Far-Difference Representations and Gaussian Behavior.*

A natural generalization of base B expansions is Zeckendorf's Theorem, which states that every integer can be uniquely written as a sum of non-consecutive Fibonacci numbers. If we allow the coefficients in the decomposition to be zero or ± 1, the resulting expression is called a far-difference representation. Alpert proved that a Fibonacci far-difference representation exists and is unique when two adjacent summands of the same sign are at least 4 indices apart and those of opposite signs are at least 3 indices apart.

We prove that a far-difference representation can be created using sets of k-Skipponacci numbers, which are generated by recurrence relations of the form $S_{n+1} = S_n + S_{n-k}$ for $k \geq 0$. Now every integer can be written uniquely as a sum of $\pm S_n$'s such that every two terms of the same sign are at least $2k + 2$ indices apart, and every two terms of opposite signs are at least $k + 2$ indices apart. Additionally, we prove that the number of positive and negative terms in given k-Skipponacci decompositions converges to a Gaussian. We conclude by proving that for any choice of k, the probability of finding a gap of length $j \geq 2k + 2$ decays geometrically, with decay ratio equal to the largest root of the given k-Skipponacci recurrence. (Received September 16, 2013)

1096-VO-2009 **George Shakan*** (gshakan@uwyo.edu), University of Wyoming Department of Mathemati, Laramie, WY 82072, and **Antal Balog**. *On the Sum of Dilations of a Set.*

Let p and q be relatively prime positive integers and A a finite subset of the integers. We prove that $p \cdot A + q \cdot A$ cannot be smaller than $(p + q)|A| - C_{p,q}$ where $C_{p,q}$ is a constant only depending on p and q. (Received September 17, 2013)

1096-VO-2150 **Nathan G McNew*** (nathan.g.mcnew.gr@dartmouth.edu), 6188 Kemeny Hall, Hanover, NH 03755. *Sets of integers which contain no three term in geometric progression.*

The problem of looking for subsets of the natural numbers which contain no 3-term arithmetic progressions has a rich history. Roth's theorem famously shows that any such subset cannot have positive upper density. In contrast, Rankin in 1960 suggested looking at subsets without geometric progressions, and constructed such a subset with asymptotic density about 0.719. More recently, several authors have found upper bounds for the upper density of such sets. We significantly improve upon these upper bounds, and demonstrate a method of constructing sets with a greater upper density than Rankin's set. This construction is optimal in the sense that this method gives a way of effectively computing the greatest possible upper density of a geometric-progression-free set. Finally, we show that geometric progressions mod N behave more like Roth's theorem in that one cannot take any fixed positive proportion of the integers modulo a sufficiently large value of N while avoiding geometric progressions. (Received September 17, 2013)

1096-VO-2232 **Edward Early*** (edwarde@stedwards.edu), St. Edward's University, 3001 S Congress Ave, Austin, TX 78704. *Decent Polynomials.* Preliminary report.

A polynomial of degree n with integer coefficients is called *nice* if it has integer roots and all of its derivatives have integer roots, for a total of $\frac{n^2+n}{2}$ distinct integers. Since nice polynomials have not been found in degrees higher than 3, we search instead for *decent* polynomials, where only the polynomial and its first derivative must possess $2n - 1$ distinct integer roots. This leads to some examples in degree 4 related to sums of squares, and a tantalizing system of Diophantine equations for degree 6. (Received September 17, 2013)

1096-VO-2240 **Vincent J. Matsko*** (vince.matsko@gmail.com), 19 Lambert Dr., Princeton, NJ 08540. *A Collatz-Like Iteration.* Preliminary report.

Consider the following iterative procedure: Begin with an integer written in base 10. If the integer is divisible by 3, then divide by 3; otherwise, reverse the digits and add 1. It is not hard to show that this process either reaches 1 or gets caught in a cycle. A *Mathematica* routine shows that all numbers up to 1,000,000 reach 1 unless they get caught in the cycle $(14 \to 42 \to 14)$, which happens 90,901 times. Carried out in base 8, this procedure first results in a cycle, of length 7, at 269,573. In base 244, the first cycle encountered is of length 23 and begins with 455,504. Changing the divisor, 3, to another number also raises numerous questions. Interesting features of this procedure are graphically depicted with *Mathematica.* (Received September 17, 2013)

1096-VO-2286 **Ken McMurdy*** (kmcmurdy@ramapo.edu). *Applying a Galois Transformation to the Roots of a Polynomial.*

Suppose $p(x)$ is a polynomial with coefficients in some field K. It is easy to apply a few very basic transformations to the roots of $p(x)$ (without finding the roots first). For example, we may add the constant $c \in K$ to each root by computing $p(x - c)$, and we may reciprocate the roots (if nonzero) by computing $x^n p(1/x)$ where n is the degree. But what if the transformation is a more general rational function? In this talk we will define a class of "Galois transformations," and present a method for applying such transformations to the roots of a polynomial. One family of examples arises from the multiplication by m map on an elliptic curve, and we will conclude with an application of the result in this case. (Received September 17, 2013)

1096-VO-2367 **James L Ricci*** (jamricci@gmail.com), Department of Mathematics and Comp. Sci., Wesleyan University Science Tower 655, 265 Church Street, Middletown, CT 06459.
Finiteness Results for Regular Ternary Quadratic Polynomials. Preliminary report.

Any quadratic polynomial can be written in the form $f(x) = Q(x) + l(x) + c$ where Q is a quadratic form, l is a linear form, and c is a constant; it is called regular if it represents all the integers which are represented locally by the polynomial itself over $\mathbb{Z}_p$ for all primes p. Given a positive definite Q, we can associate certain types of quadratic polynomials to a coset of a $\mathbb{Z}$-lattice in order to view quadratic polynomials through the geometric perspective of quadratic spaces and lattices. In this talk we will define an invariant called the conductor, a notion of a semi-equivalence class of a regular quadratic polynomial and present our result: Given a fixed conductor, there are only finitely many semi-equivalence classes of primitive regular integral quadratic polynomials in three variables. (Received September 17, 2013)

1096-VO-2452 **Ding Ding*** (ding@math.binghamton.edu), Department of Mathematical Sciences, Binghamton University, Binghamton, NY 13902-6000. *Automorphism group schemes of p-divisible groups over fields of positive characteristic.*

The p-divisible groups, or more generally formal group schemes over fields of positive characteristic have been studied actively since mid 20th century, especially after the influential work of Dieudonné and Manin. In this talk we report some progress on the study of the automorphism group schemes of p-divisible groups, with a focus towards a particular type, namely, the canonical lifts of the p-kernels of p-divisible groups. (Received September 17, 2013)

1096-VO-2513 **Evan P Dummit***, dummit@math.wisc.edu. *Bounds on the Number of Extensions of a Number Field with Bounded Discriminant and Specified Galois Group.* Preliminary report.

The problem of asymptotics for the number of number field extensions L/K with a given degree n has a long history: a folk conjecture holds that the number $N_n(X)$ of such number fields with relative discriminant less than X is asymptotic to $c_n X$ as X grows and n is fixed. In a 2006 paper of Ellenberg and Venkatesh, the authors improved the best known general result, due to Schmidt: they proved that $N_n(X) \ll X^{\exp(C\sqrt{\log n})}$. I will discuss generalizations, employing some of their techniques, that improve the best known asymptotic bounds for the number $N_{n,G}(X)$ of relative extensions with Galois closure isomorphic to G. (Received September 17, 2013)

1096-VO-2595 **Amita Malik*** (amalik10@illinois.edu), 1409 W Green Street, Urbana, IL 61801, and **Florin Stan** and **Alexandru Zaharescu**. *Siegel's trace problem and character values of finite groups.*

We give some applications of Siegel's trace problem and related results to character values of finite groups. In addition, we discuss algorithms to compute the length of a cyclotomic integer and the set of cyclotomic integers with Siegel norm bounded by a given positive real number. (Received September 17, 2013)

1096-VO-2605 **Uthoomporn Jongthawonwuth*** (aor_utoo@hotmail.com), Department of Mathematics and Computer Scienc, Chulalongkorn University, Bangkok, 10330, Thailand, and **Saad I El-Zanati** and **Chariya Uiyyasathian**. *On decomposing complete multipartite graphs into 2-regular graphs.*

Let G be a 2-regular graph of odd order n consisting of any number of even length cycles and a single odd length cycle. We show that there exists a G-decomposition of the complete multipartite graph $K_{(2x+1)\times n}$ for every positive integer x. We also show a similar result if G consists of three odd length cycles. (Received September 17, 2013)

General Session on Teaching Introductory Mathematics

1096-VP-633 **Ping Ye*** (yepi@quincy.edu), Quincy University, 1800 College Ave., Quincy, IL 62301.
Online vs. Traditional On-ground Teaching for Basic Statistics.

To satisfy the needs for students who live far away from the University and working students, online teaching becomes unavoidable. This paper discusses the advantages and disadvantages for both online and traditional on-ground teaching methods for Basic Statistics. It also explores the teaching results and it reports feedbacks of students for both methods. (Received September 08, 2013)

1096-VP-1183 **Dywayne A Nicely*** (nicely@ohio.edu). *A Word on Word Problems: How Improving Reading Comprehension and Mathematics Vocabulary Can Improve Performance on Mathematical Word Problems.*

Many students declare that they are incapable of solving word problems or show displeasure when word problems are encountered. In recent years, there have been studies that show a correlation between reading comprehension skills and performance on word problems in mathematics courses. Therefore, we conducted a research project during the 2012-2013 academic year that aimed to help students increase their reading comprehension skills, mathematical vocabulary and enhance their word problem solving strategies. Our hope was to increase the students' performance on word problems in their mathematics courses but we also hoped to make each student more college-ready. This project was collaboration between Ohio University-Chillicothe (OUC) and Chillicothe High School (CHS). Including me, the project contributors consisted of the principal of CHS, and one faculty member each from the English and Mathematics departments of CHS. We tracked the progress of approximately 125 students from four sections of Algebra II and two sections of Honors Pre-calculus. At last year's JMM, we discussed an overview of the project's design and presented data that has been collected thus far. In this presentation, we will give a final report from the data collected and share our positive results. (Received September 13, 2013)

1096-VP-1396 **Patricia Anderson*** (panderson@southern.edu) and **Kevin Brown**. *College Algebra: A Comparison of Traditional and Computer Aided Approaches.* Preliminary report.

Across the nation, students in a traditional Precalculus mathematics classroom tend to have widely varied skills with many not satisfactorily completing the course. Southern Adventist University was no exception to this rule. In the 2012-2013 school year, Southern Adventist University raised the entrance requirements to the traditional Precalculus course and introduced both a traditional College Algebra course and a hybrid College Algebra course. The hybrid course utilizes an online environment for all aspects of the course while still requiring in person class attendance. We give a preliminary report on the outcomes of both College Algebra courses focusing on what worked and what needs to be changed for later implementations. We also report on the progress of those students who advanced into the traditional Precalculus course. (Received September 16, 2013)

1096-VP-1508 **Shumei C. Richman*** (richmansmc@gmail.com), 220 N. Woodlake Dr., Columbia, SC 29229. *The Use of the Order of Operations in Reading, Writing and Solving Linear Equations.* Preliminary report.

Abstract. In arithmetic, students are taught to use the order of operations to simplify expressions. However in most beginning algebra textbooks T.O.O.O. is not mentioned in the content of algebra. This research aims to answer two questions: 1. Should students continue to use the order of operations in algebra? 2. How to best incorporate the order of operations in math teaching beyond arithmetic? We have found that TOOO is crucial for students to learn linear equations well. First, it provides students with a tool to "read" equations besides solving them by rules. From the process of reading, they understand that an equation can look short and simple, but in fact is complex and requires skills to decode. For example, the equation 4x-5=12 is a sentence of seven math words: 4,x,*,-,5,=,12, among them the multiplication is invisible and therefore often neglected. Secondly, the ability of reading equations enables students to write equations for word problems. In this talk, we will discuss how to use the order of operations in reading, writing and solving linear equations. We will also discuss how TOOO provides students with an effective way of dealing with parentheses in solving certain equations, such as 2(4x-5)+3=12-2(4x-5), and 3333(8x/7-5)=9999, besides using distributive law. (Received September 17, 2013)

1096-VP-1651 **Joseph B. Liddle*** (jbliddle@uas.alaska.edu), 609 SMC Rd., Sitka, AK 99835. *Efficacy of Online Delivery of Introductory Statistics in English to Taiwanese Students.* Preliminary report.

In recent years there has been explosive growth in online education world-wide. The internet has provided an environment which is both profoundly personal in that it reaches into each person's private life and extraordinarily international as boundaries, languages and cultures are transcended. It is now possible to envision education being provided internationally provided that a common language exists between students and instructor. We conducted a pilot study to test the efficacy of teaching statistics online to 40 Chinese speaking students in Taiwan. We found that test scores increased from pre to post test ($p<0.0001$). Although the majority of students reported that they liked the online course, and that they learned some English, they also said that they needed better

translation functions built into the website especially terminology used in statistics. We found that email alone is not an effective to communicate with Taiwanese students who use cell phones to communicate rather than email. Key words: online education, statistics education, Taiwan. (Received September 16, 2013)

1096-VP-1688 **Ryo Ohashi*** (ryoohashi@kings.edu), 133 North River Street, Wilkes-Barre, PA 18711.
How to retain a perfect attendance rate at introductory level courses. Preliminary report.

At many math conferences, there are tremendous opportunities to learn all sorts of cool pedagogies for introductory level math courses, and we gain new teaching strategies through the opportunities. As a result, we are hoping that our students do learn math out of our efforts. However, I feel that we may be forgetting one big assumption in order to make them work, that is, if our students actually attend each class and if they study.

In this presentation, the presenter will discuss how to get started to succeed your pedagogical wishes and/or dreams. In other words, I will provide the audience how to increase students' attendance rate and how to catch their study their poor habit as early as possible since I have been implementing this secret "HOW" in my intro level class rooms over 10 years. If time permits, a student retention issue will be discussed.

If you are upsetting because of horrible attendance rates, then this is "THE" place to stop by to cure your stress. Of course, graduate teaching assistants are truly welcomed to join. (Received September 16, 2013)

1096-VP-1893 **Grethe Hystad*** (ghystad@math.arizona.edu), Department of Mathematics, The University of Arizona, 617 N. Santa Rita Ave., P.O. Box 210089, Tucson, AZ 85721.
Supplemental Instruction in Precalculus.

In this talk we will describe the course, Precalculus Supplemental Instruction Seminar, currently offered at the University of Arizona. This course is an inquiry based course with the goal of increasing the retention and success rate of incoming freshmen enrolled in Precalculus. We will describe the structure, types of problems, and the model of the course followed by some results. (Received September 16, 2013)

1096-VP-2122 **Daniel J. Ghezzi*** (danielghezzi@kings.edu). *Effective use of Chi-square Procedures in an Introductory Statistics Course.*

One of the primary challenges in teaching a one semester introductory statistics course is having sufficient time to effectively teach the many statistical inference procedures required in the course. The enrollment in these courses is mainly first or second year students. Thus, the many lectures devoted to studying descriptive statistics, probability, and sampling distributions ultimately lead to a less than desirable amount of time for the main topics of the course - Hypothesis Testing and Confidence Intervals. In this talk I will demonstrate how instructors can free up one to two lectures by effectively adopting Chi-square procedures for use in the one and two population categorical variable(s) problems. (Received September 17, 2013)

1096-VP-2301 **Don Small*** (don.small@ymail.com), 28 Pine Street, Cornwall on Hudson, NY 12520. *A Contemporary Approach to Intermediate Algebra.*

A contemporary approach focuses on three goals (1) developing problem-solving skills, (2) helping students to become effective learners, (3) developing student confidence and motivation. The primary medium for addressing these goals is solving realistic word problems. Homework exercises are presented in word problem format rather than the "skill and drill" format. Strong emphasis is placed on modeling word problems and interpreting solutions, interpreting charts and graphs, and questioning. The one semester course is designed to prepare students for a credit bearing course such as 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 17, 2013)

1096-VP-2329 **Christopher Schroeder***, c.schroeder@moreheadstate.edu. *High School (through College) Algebra.*

Through a series of events over the past few years, Morehead State University has been able to offer numerous college-level courses which are taught in the high schools of our service region. We will focus on the largest such offering, College Algebra, and consider some of the opportunities and challenges presented by this program. In particular, we will consider techniques used to ensure that the students in the high schools are getting a course and experience that is comparable to the college students. Further, we will look at the effectiveness of the program and consider the long-term impact of this, and similar endeavors. (Received September 17, 2013)

1096-VP-2519 **Vera Hu-Hyneman*** (huhynev@sunysuffolk.edu), Department of Mathematics, Suffolk County Community College, 533 College Road, Selden, NY 11784, and **Alexander G. Atwood** (atwooda@sunysuffolk.edu), Department of Mathematics, Suffolk County Community College, 533 College Road, Selden, NY 11784. *Innovative Student Projects on Exponential Growth and Decay in Pre-calculus.*

Students often say, "Why do we need to study exponential functions in pre-calculus?" We will describe a group project that will give students specific instructions: pretend that they are employees of the Department of Environmental Protection and the Center for Disease Control. They have been sent to investigate the findings of scientists on a specific environmental case of their choosing. In one example of a project, bacteria are rapidly growing in a river, and the President of the United States has called and requested a full report on the alarming increase in the population of the bacteria in the river, based on exponential growth. After a few years have passed, exposure of the bacteria to radioactive isotopes has caused the population of the bacteria to decay exponentially. The group of students has to model this growth and decay, and they have to write a follow-up report. (Received September 17, 2013)

1096-VP-2530 **Alexander G. Atwood*** (atwooda@sunysuffolk.edu), Department of Mathematics, Suffolk County Community College, 533 College Road, Selden, NY 11784, and **Vera Hu-Hyneman** (huhynev@sunysuffolk.edu), Department of Mathematics, Suffolk County Community College, 533 College Road, Selden, NY 11784. *Using Algebra in the Classroom to Understand the Way in which Automobiles Collide.*

The concepts of Intermediate Algebra can provide surprising qualitative and quantitative insight into the way in which automobiles crash into fixed barriers and into other automobiles. Using linear equations in one variable, quadratic functions and some simple concepts from physics, one can analyze and understand what really happens when a car crashes. (Received September 17, 2013)

General Session on Teaching Mathematics Beyond the Calculus Sequence

1096-VQ-70 **Cynthia Huffman Woodburn*** (cwoodburn@pittstate.edu). *Course Redesign Applied to a History of Math Course.* Preliminary report.

"Course Redesign" is currently a fashionable catchphrase in higher education. This presentation will focus on how principles of course redesign were applied to a History of Math course in order to achieve better learner outcomes and to improve the educational experience for undergraduate mathematics majors at a regional university. The redesign involved a shift from a professor-centered pedagogy to one in which students are more active learners. Since recent cognitive science research shows "higher level learning is enhanced by an experience in which students are actively engaged with the content and with each other" (Turner & Carriveau, Next Generation Course Redesign, citing Association for the Study of Higher Education, 2007), the redesign entailed utilizing a collection of cooperative hands-on activities so that students are provided active learning experiences and opportunities to engage with the interdisciplinary content (history and mathematics) as well as opportunities to engage with other students in the course, in order to move students from lower level cognitive skills on Bloom's Taxonomy to higher levels. Another part of the course redesign involved incorporating available information technology such as video, applets, etc... into the course. (Received July 02, 2013)

1096-VQ-183 **Leon Kaganovskiy*** (leonkag@gmail.com), 1233 E 19TH ST APT 6J, BROOKLYN, NY 11230. *Applications of Maxima CAS to Differential Equations.*

In this presentation we would like to explore using freely available Maxima CAS to create codes which significantly enhance students' learning of more complicated Differential Equations concepts. Among the topics considered are the creating slope fields and phase portraits, population dynamics, object cooling, RK methods, and Ecological models. (Received August 14, 2013)

1096-VQ-540 **Michelle DeDeo*** (mdedeo@unf.edu), 1425 Candy Ct., Saint Johns, FL 32259. *The Conundrum of Teaching Finite Mathematics.*

Finite mathematics is a course filled with disparate topics such as model building, matrices, linear programming and combinatorics. As mathematicians, we appreciate and see the beauty in each one of these topics. The purpose of the course is to give a survey of mathematical analysis and techniques used in the working world as well as giving students experiences with organizing information and then analyzing the information.

Students at many colleges and universities take the class for one and only reason: to get a passing grade in a mathematics class in order to graduate. Knowing this, we can guess that these students aren't "good at math." So the question is: how can we teach these students effectively and how much content can we hoist upon them before we lose them?

In this talk I explore a few areas where balancing content and substance may lead to a better student (and teacher!) experiences. (Received September 05, 2013)

1096-VQ-1082 **Tetsuya Yamamoto*** (yama3@ou.edu), Norman, OK 73019. *Analyzing Students' Difficulties with Proving in Light of the Structure of Proof Construction.* Preliminary report.

This study aims to investigate student's difficulties with proving in light of the structure of proof construction and to provide practical suggestions for pedagogical purposes. The main target population in this study was those students in Introduction to Algebra, Analysis, and Topology. In analyzing their proofs, this study offers two frameworks: (a) for modeling the structure of proof construction; (b) for analyzing students' difficulties in proving. The data was collected through students' exams, in-class and individual problem-solving sessions. So far, the results indicate the following as possible major causes of students' difficulties: (1) mismanagement of the conclusion of the given statement, (2) lack of knowledge of key concepts including their definitions, notations, and meanings, (3) lack of tenacity to try to rephrase an object, (4) lack of precision in dealing with an object. The results led to the conjecture that the knowledge of the structure of proof construction itself could help students advance their reasoning processes in proving. The findings of this study may contribute to what could be taught in both proof-based and transition to proof courses. (Received September 12, 2013)

1096-VQ-1161 **Milos Savic*** (savic@ou.edu), **Melissa Mills** (memills.math@gmail.com) and **Robert Moore** (moorer@andrews.edu). *Mathematicians' views on transition-to-proof and advanced mathematics courses.* Preliminary report.

This study explores mathematicians' views on 1) knowledge and skills students need in order to succeed in subsequent mathematics courses, 2) content courses as transition-to-proof courses, and 3) differences in the proving process across mathematical content areas. Seven mathematicians from three different universities (varying in geographic location and department size), were interviewed. Precision, sense-making, flexibility, definition use, reading and validating proofs, and proof techniques are skills that the mathematicians stated were necessary to be successful in advanced mathematics courses. The participants agreed unanimously that a content course could be used as a transition-to-proof course under certain conditions. They also noted differences in the proving processes between abstract algebra and real analysis. Results from this study will be used to frame a larger study investigating students' proof processes in their subsequent mathematics content courses and investigating how these skills can be incorporated into a transition-to-proof course. (Received September 13, 2013)

1096-VQ-1377 **Scott Beaver*** (beavers@wou.edu), 1451 Meadowglen Ct., Monmouth, OR 97361. *An IBL Approach to Advanced Calculus That Incorporates Proficiency.*

Fluency with the relevant definitions and theorems is a necessary condition for student success in Advanced Calculus, as is the ability to quickly solve problems which require little more than straightforward application of a definition or theorem. This is the notion of *proficiency*, an approach that is well-established in second-language instruction and which has recently gained traction in broader K-12 education. I offer the architecture that I use in an IBL Advanced Calculus course to ensure such fluency, including an appropriate IBL/proficiency ratio. (Received September 15, 2013)

1096-VQ-2000 **Joyati Debnath*** (jdebnath@winona.edu), Department of Mathematics and Statistics, Winona State University, Winona, MN 55987. *Learning to Write Arguments.*

Studying and learning mathematics becomes most challenging when it requires writing of what one has comprehended. Specifically writing arguments is frustrating since it forces one to acquire a very deep and powerful sense of understanding of what it is to write. When one makes an effort to use the fundamental ideas of mathematics and string through them to make a necklace of arguments, then it may be said some learning occurred. In this presentation author will engage the audience with different approaches that were used at different times to assure the formation of that bridge for students to move on from calculus sequences to real analysis, abstract algebra and/or number theory courses. (Received September 17, 2013)

1096-VQ-2163 **Steve Balady*** (sbalady@umd.edu), **Rebecca Black** (rblack1@umd.edu), **Josh Ballew** (jballew@umd.edu) and **Elizabeth Fleming** (fleming1@umd.edu). *We Started a Directed Reading Program And So Can You.*

The Directed Reading Program (DRP) pairs undergraduate students with graduate student mentors for semester-long independent study projects. We introduced this program to the math department at the University of Maryland in Fall 2011 and it has been growing rapidly in quantity and quality of participation. Over the past 6 semesters the DRP has had an average of 13 pairings per semester, with a total of 77 projects completed (see http://drp.math.umd.edu for details). Our talk will include a brief explanation of the program and its history, the challenges and questions we have faced, and an outline for how to establish a successful program.

The DRP enables undergraduates from a range of mathematical backgrounds to explore a mathematical topic or interest that may complement, extend, or even eclipse their mathematics coursework. Additionally these one-on-one pairings provide a rare and welcome space for undergraduate and graduate student interactions about mathematics as well as about the world of graduate study. We believe this program could be implemented at many institutions and we will discuss key steps for creating similar programs. The DRP is a feasible, practical, and successful means of engaging undergraduates with mathematics beyond the calculus sequence. (Received September 17, 2013)

General Session on Assorted Topics

1096-VR-252 **Patricia Baggett*** (baggett@nmsu.edu), Dept of Mathematical Sciences, MSC 3MB P.O. Box 30001, New Mexico State University, Las Cruces, NM 88003, and **Andrzej Ehrenfeucht** (andrzej.ehrenfeucht@colorado.edu), Computer Science Department, University of Colorado, P.O. Box 430, Boulder, CO 80309-0430. *Arithmetic algorithms taught in schools.* Preliminary report.

The requirement that students understand what they are doing and not just memorize procedures (rote learning) has been the leading educational principle since at least 1945. But consecutive reforms based on this principle have not produced the expected results. The problem may lie in the algorithms that are taught in schools. They were designed to be used in an automatic way by human computers, and to be efficient and verifiable, but not to be easy to understand. We will describe alternative algorithms for addition, subtraction, and multiplication based on Napier's work on location numbers in his Rabdology, and an algorithm for division based on an approximation method used by Brahmagupta. These algorithms are designed on clear mathematical principles, and require that a user make some decisions that depend on the specific numbers involved in the computation. And because these algorithms require a user's decisions, they are not routine and cannot be executed in an automatic way. The algorithms are less efficient than the standard ones, but sufficient for all numbers within the range that is covered in elementary and middle grades. (Received August 23, 2013)

1096-VR-366 **Jathan W. Austin*** (jwaustin@salisbury.edu), Dept. of Mathematics and Computer Science, Salisbury University, 1101 Camden Avenue, Salisbury, MD 21801. *Matrices, Twin Pythagorean Triples, and Pell Numbers.*

A matrix for a linear transformation that maps Pythagorean triples into Pythagorean triples is called a Pythagorean-triple-preserving matrix (PTPM). In this talk, the presenter will show how to generate the set of all leg-leg twin Pythagorean triples using powers of one PTPM. Several identities for Pell numbers that follow from this construction will be discussed. (Received August 30, 2013)

1096-VR-522 **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 from the Western and Plains states. These materials–both paper and electronic–are classroom ready, and are developed and piloted in consultation with Tribes in the Rocky Mountain and Plains. This work is an NSF TUES Type 2 funded project. (Received September 05, 2013)

1096-VR-839 **Padraig M. McLoughlin*** (mcloughl@kutztown.edu), 265 Lytle Hall, Dept. of Mathematics, Kutztown University of Pennsylvania, Kutztown, PA 19530. *Turn Off Machines: Turn On Minds!*

'Appropriate' use of technology has been a ubiquitous phrase in mathematics curriculum guidelines for years. What 'appropriate' means in this context is the topic of this talk. We submit that calculators should be banned in most college mathematics courses.

In a recent article in the Washington Post, a defender of calculators maintains "'[students] are not so great at computing numbers on the back of a notebook, but calculators have expanded students' 'ease and grasp' of math' & 'can jump past the grunt work to get to more sophisticated levels of analysis.' Kids whose arithmetic skills may be weak but they can rely on calculators 'to do that work, and they can still do algebra,' 'It's just like word processing,' he said. 'There are people who can't spell . . . but word processing can allow them to express things well and be creative.'"

We shall argue for unshackling minds by shedding calculators, we shall appeal to reason, and we shall attempt to retort some (in)famous arguments for the use of a calculator (such as previously quoted).

We submit that the use of calculators hinders students' understanding of mathematics by deemphasising basics, creating or reinforcing an external locus of control, and reducing students' reasoning skills. (Received September 11, 2013)

1096-VR-1049 **Homer W. Austin*** (hwaustin@salisbury.edu), Department of Mathematics and Comp. Sci., Salisbury University, 1101 Camden Avenue, Salisbury, MD 21801. *Transforming Sequences of Pythagorean Triples.*

Published articles in professional mathematics journals have great potential for change not only in research, but also in instruction. A short article published by the late W.V. Quine of Harvard University is testimony to this fact. The purpose of this talk is to indicate both teaching activities and ongoing research originally motivated by Quine's article. (Received September 12, 2013)

1096-VR-1188 **Kimberly Phillips*** (phillipskn@washjeff.edu). *Tiling m-Deficient Mutilated Chessboards with m-Polyominoes.* Preliminary report.

For natural numbers m and n, an $n \times n$ chessboard is called *m-deficient* if m divides $n^2 - 1$. A chessboard is called *mutilated* if a single square is removed from the board. We analyze tiling m-deficient mutilated chessboards with m-polyominoes where an *m-polyomino* is a geometric figure with m congruent squares placed edge to edge. An m-polyomino arranged such that $m-1$ squares are placed in a straight line with the last square perpendicular to a square on the end, making an L-shape, is called an *L-polyomino of order m.* As long as $n \geq 2$ and $n \neq 5$, every 3-deficient mutilated chessboard can be tiled with L-trominoes. We also discuss our recent work with tiling m-deficient mutilated chessboards with L-polyominoes of order m and with general m-polyominoes. (Received September 13, 2013)

1096-VR-1204 **Susan E Thompson*** (sthompson@otterbein.edu), Mathematical Sciences Department, Otterbein University, 1 S Grove St, Westerville, OH 43081. *Flexible Option for Developmental Mathematics.*

Can the use of an adaptive learning system in delivering intermediate algebra to university students successfully prepare them for their university-wide mathematics requirement? Our small, private, comprehensive institution has used ALEKS [Assessment and LEarning in Knowledge Spaces], an adaptive learning system that individualizes assessment and learning, as an option for entering students to improve mathematics placement in the summer prior to matriculation for the past seven years, with good success. Unfortunately, not all incoming students are able to use or complete this option due to summer work and family commitments, internet access problems, or instructional support issues. In an effort to offer this flexible, individualized instruction with technological and instructional support during the academic year, we piloted use of ALEKS as the teaching/learning tool in a flexible semester option. Information presented at this session will include a description of the model employed, results from 2012-13, and preliminary success rates in subsequent courses. (Received September 13, 2013)

1096-VR-1434 **Mari Castle*** (mfc7379@kennesaw.edu) and **Victoria Powers**. *Connecting Pairwise and Multistage Election Outcomes.*

It is well known that a pairwise election winner, i.e., Condorcet Winner, is not necessarily the winner determined by positional voting methods such as plurality, ant-plurality, and the Borda Count. In recent work, Donald Saari and Tomas McIntee have established when Condorcet and positional election winners can disagree, or must agree. Their work connects pairwise tallies with admissible positional outcomes and provides the necessary and sufficient conditions ensuring that the Condorcet winner is the plurality winner, as well as identifying when a profile exists where each candidate is a winner using distinct positional election methods. In this talk, we develop similar results for multi-stage elections, such as instant runoff. (Received September 15, 2013)

1096-VR-1552 **Jeremy J Yagle*** (j.j.yagle@iup.edu). *Using Boundary Following Algorithms to Identify User-Defined Mountain Bike Trails in Topographic Map Images.*

Given an aerial image and a corresponding topographical map, I present a series of steps to extract elevation information for a user-defined mountain bike trail drawn on the map. The use of a Digital Elevation Model (DEM) provides the needed elevation data, and several basic image processing techniques are then used to generate both a two-dimensional elevation profile and three-dimensional trail profile. The foundation of the process relies on the use of a Moore Boundary Following Algorithm incorporating radial sweep techniques.
(Received September 16, 2013)

1096-VR-1796 **Suraj Uttamchandani*** (slu1@geneseo.edu). *Integrating Calculus and Residence Life: Does living with calculus help students learn calculus?*

This past fall, SUNY Geneseo piloted a new program in which incoming students lived together, took calculus together, and had the opportunity to attend office hours in their residence hall. As a teaching assistant for this Living-Learning Community and a senior math major, I had a chance to explore the effects of this interaction between dorm life and academic life. In this talk, we will discuss the effectiveness of integrating mathematics into residence life; how supplementary peer tutoring affected student learning; and how opportunities such as this one engage students of various majors. We will also discuss student feedback to the experience and its effectiveness as well as possible ways to improve and expand the program. (Received September 16, 2013)

1096-VR-1865 **McKenzie R Lamb*** (lambm@ripon.edu), 642 Woodside Ave, Ripon, WI 54971. *Differentiability at Infinity: Wrapping Curves Around the Sphere.* Preliminary report.

Suppose a curve in the plane has two distinct "ends" that stretch off toward infinity in different directions. Under the inverse image of stereographic projection, the ends of the curve will approach the North Pole on the 2-sphere. How do they meet? In particular, if we fill in the point at the North Pole, we have a closed curve on the sphere. Under what conditions is this curve differentiable at the North Pole? We investigate this question in the case where the original curve in the plane is the graph of a function. (Received September 16, 2013)

1096-VR-1955 **David S. Torain, II*** (david.torain@hamptonu.edu). *Office Management: A Markov Model.*

This presentation will introduce a Markov model to structure the trafficking of tasks in a given governmental office consisting of three components. The theory of the Markov model used is developed clearly to justify its implementation in a practicable manner. The Fleet Support Office of the Naval Personnel Research and Development Center is used as a typical case. The probabilities of predicted office states will be represented from a matrix equation. A long range prediction of various office states will be computed using a mean passage of time matrix M. This matrix will allow for estimation of the cost of running the governmental office per unit time in a weighted cost equation. The Markov model allows government managers to assign tasks to a particular office component that predicts functional office states at acceptable productivity rates with more efficient use of manpower resources. (Received September 16, 2013)

1096-VR-2098 **Jenna Price Carpenter*** (jenna@latech.edu), PO Box 10348, Ruston, LA 71272. *Using Circuits to Teach Truth Tables: Making the Math Real.*

Multiple places in our mathematics curriculum we cover a short chapter on logic - at the beginning of our pre-calculus course, in our introduction to proof course, and in our discrete math course. Particularly for non-math majors and even beginning mathematics education majors, logic can seem like a distant and theoretical topic without much application to the "here and now". We have used a one-day in-class lab on series and parallel circuits to help teach the concepts of "and" and "or" statements. Students (even those with absolutely no background in circuits) quickly grasp both concepts, aided with the visual and hands-on lab activities, and are able to translate even complicated compound series and parallel circuits and compound "and" and "or" logic statements back and forth with ease. In addition, the activity helps reinforce that the seemingly abstract concepts in logic are integrally connected with real world applications that they all see and use every day (cell phones, computers, etc.). We will review the instructional approach and give attendees an opportunity to participate in some hands-on lab activities. (Received September 17, 2013)

1096-VR-2125 **Marc S. Renault*** (msrenault@ship.edu), 1871 Old Main Drive, Shippensburg, PA 17257. *Properties of the (a, b)-Fibonacci Sequence, Modulo m.*

For integers a and b, we consider the (a, b)-Fibonacci sequence F defined by $F_0 = 0$, $F_1 = 1$, and $F_n = aF_{n-1} + bF_{n-2}$. $F \pmod m$ is periodic with period denoted $\pi(m)$. The rank of $F \pmod m$, denoted $\alpha(m)$, is the least positive r such that $F_r \equiv 0 \pmod m$, and the order of $F \pmod m$, denoted $\omega(m)$, is $\pi(m)/\alpha(m)$.

We pull together results on $\pi(m)$, $\alpha(m)$, and $\omega(m)$ from the classic case $a = 1$, $b = 1$, and generalize them to accommodate arbitrary integers a and b. Matrix methods are used to provide elementary proofs. (Received September 17, 2013)

1096-VR-2177 **Robert M. Sulman*** (sulmanrm@oneonta.edu). *Proving Special Cases using Alternate Methods.* Preliminary report.

Sometimes a special case of a more general result can be proven using methods that may not be sufficient to prove the general fact. This approach has the advantage of (a) Bypassing a proof (of general result) not accessible to students of a certain mathematical level or (b) Highlighting the notions utilized in the alternate technique.

Examples are seen in a variety of topics. For instance:

(i) Determining the turning point(s) in the graph of (certain) rational functions without using Calculus (ii) Fermat's Little Theorem (iii) Special cases of Cauchy's Theorem for Finite Groups (iv) Sylow's Theorem (normal Sylow subgroup criteria)

Highlighted notions from above examples include the discriminant of a quadratic, congruence (modulo n) is preserved under multiplication, Lagrange's Theorem, group actions & the permutation representation, order of "psi"(x) divides order of x when "psi" is a homomorphism of finite groups, and the Class Equation.

Basic divisibility facts are reinforced in these examples as well. For instance: p does not divide m! if p is a prime greater than m.

Being resourceful can be fun and strengthen one's understanding of connections within the material. (Received September 17, 2013)

1096-VR-2192 **Anthony F. Filiziani*** (wcdt@iup.edu), 711 South 6th St. Apt. # 5, Indiana, PA 15701. *Image Enhancement Algorithm for Under-Water Images.*

The art of imagery has been one of the most revolutionary turning points of the 17th century. Since its' discovery, the technology upon which it was founded has significantly improved over the last 300 years. While the tools used to create an image have significantly improved, there will always be issues concerning its quality from the original source. No matter where an image will be taken, there will undoubtedly be issues with an images' quality once extracted. These issues include, Color Attenuation, "Noise", Reflection and Refraction, and many others; and while most of these enhancement issues can be addressed with current technological approaches, they can become more complex for under-water imagery.This paper will focus on an algorithm to enhance under-water images due to the additional sources of "noise" that otherwise would not be present under normal circumstances. Initially, a brief description of underwater imagery will be discussed, and the issues pertaining will be explained as well. Once established, the format of the algorithm will be introduced, explaining each process and its purpose for the overall process of enhancement. Once the algorithm has been completely explained, the results will be reviewed with a brief description of comparison to the original image. (Received September 17, 2013)

1096-VR-2221 **Hope K Snyder*** (snyderhk@jay.washjeff.edu), **Dorothy Klein**, **Ryann Cartor**, **Rachel Carleton** and **Andrew Tonge**. *How Low Can You Go? Estimating the Maximum of a Polynomial.*

Given a homogeneous polynomial of degree k in n variables with leading coefficients a_j, there exists some constant C_k such that the maximum of the polynomial, denoted $||p|| = \max |p(x_1, x_2, \ldots, x_n)|$ when $x_i \in [0, 1]$, can be estimated by $\sum_{j=1}^{n} |a_j| \leq C_k * ||p||$. Finding the bound for C_k allows for better estimates of the size of homogeneous polynomials. Estimating the maximum is particularly useful for polynomials that have degree $k > 3$ or number of variables $n > 3$ as finding the maximum for these expressions using calculus becomes increasingly difficult. This is joint work with Ryann Cartor, Rachel Carleton, and Dorothy Klein and Dr. Andrew Tonge completed during the 2013 REU at Kent State University. (Received September 17, 2013)

1096-VR-2222 **Dorin Dutkay** and **John Haussermann*** (jhaussermann@knights.ucf.edu), Department of Mathematics, University of Central Florida, 4000 Central Florida Blvd. P.O. Box 161364, Orlando, FL 32816. *Tiling properties of spectra of measures.*

We investigate tiling properties of spectra of measures, i.e., sets Λ in $\mathbb{R}$ such that $\{e^{2\pi i\lambda x} : \lambda \in \Lambda\}$ forms an orthogonal basis in $L^2(\mu)$, where μ is some finite Borel measure on $\mathbb{R}$. Such measures include Lebesgue measure on bounded Borel subsets, finite atomic measures and some fractal Hausdorff measures. We show that various classes of such spectra of measures have translational tiling properties. This lead to some surprizing tiling properties for spectra of fractal measures, the existence of complementing sets and spectra for finite sets with the Coven-Meyerowitz property, the existence of complementing Hadamard pairs in the case of Hadamard pairs of size 2,3,4 or 5. In the context of the Fuglede conjecture, we prove that any spectral set is a tile, if the period of the spectrum is 2,3,4 or 5. (Received September 17, 2013)

1096-VR-2356 **Chuang Peng*** (cpeng@morehouse.edu), Department of Mathematics, Morehouse College, Atlanta, GA 30314. *Algebraic Structure of Fuzzy Numbers.* Preliminary report.

This is the latest report in a series of work on developing a formal fuzzy number system, operations and its algebraic structures based on Zadeh's extension. The properties of fuzzy addition were discussed in an earlier work. In fact, the fuzzy numbers form a monoid under the fuzzy addition. It looks into its inverse operation - subtraction and develop a group structure for fuzzy number system, using the equivalent classes defined by symmetric fuzzy numbers. Moreover, on the fuzzy multiplication defined by Zedeh's extension, it proves that the well-known distributive laws hold, up to the equivalence relation. It then looks into the integral domain structure of the fuzzy numbers modulo by the equivalence classes defined by symmetric fuzzy numbers. Further algebraic properties, such as factorization, irreducibility and Euclidean division algorithm, will be discussed. (Received September 17, 2013)

1096-VR-2403 **Qingxia Li** (liq@lincolnu.edu), 701 S Providence Road, Apt 1I, Columbia, MO 65203, and **James Schrader*** (james.schrader338@my.lincolnu.edu), 821 Taylor Drive, Department of Mathematics, Lincoln University, Jefferson City, MO 65102. *Infimal Convolution of Convex Set-Valued Mappings.*

In this presentation, we first defined the supremum of a Set-valued mapping in a real linear topological space which is partially ordered by a Dedikind complete cone. Then we would tackle the convexity of set valued mappings and derive some infimal convolution properties for convex valued mappings. (Received September 17, 2013)

1096-VR-2536 **Jonathan R Wayland*** (jonwayland47@yahoo.com), DuBois, PA 15801. *Modifications of Watershed Segmentation in Digital Image Processing.*

There are multiple methods to attempt to segment objects in digital image processing. This paper focuses on one specific method, watershed segmentation. There are multiple steps in this proposed process where the results allow you to visualize the accuracy of segmentation. Accuracy in this case is defined by how many objects are successfully identified when the segmentation takes place.

All of the processing will take place in Matlab where the code is given in the Appendices. The "Original Method" was adapted by Mathworks, the Matlab website. Here an example of segmented peaches is given and the steps of the process are also given. Following these steps, an image of baseballs were segmented using the same process. The "Original Method" and the example of segmented peaches also follow the same code except for some arguments that are specific to the baseball image.

Basing the segmentation process of the provided example, alterations were done considering specific steps that resulted in fluctuations in the original image. With a total of three different changes, and four total altered results, it was shown that better, similar and worse results were obtained. The altered methods' codes are also given in the Appendix. (Received September 17, 2013)

1096-VR-2539 **Scott A Rega*** (s.a.rega@iup.edu), 4608 Greenfield Road, Bethlehem, PA 18017. *Airport Simulation and Optimization of Passenger Flow using Arena.* Preliminary report.

The model simulation of the Newark Liberty International Airport focuses on Terminal C, United Airways. Using passenger flow from their initial arrival through transportation and various check-in methods, I was able to find different scenarios and results of how quickly each customer progresses and also the total amount of customers which move through the system. Using Process Analyzer, I was able to come up with an optimal method to increase multiple utilization functions while still preserving the integrity of the waiting and total times of passengers within the system. A goal of this project is to save time for the check-in line queues, so therefore one thing I will modify in the simulation is the amount of resource workers for the airline, therefore to accommodate more customers at once. There could be more stations for the heavier populated airlines, such as United Airways in Newark Airport. (Received September 17, 2013)

1096-VR-2577 **Horia I. Petrache*** (hpetrach@iupui.edu), 402 N. Blackford St., LD154, Physics, IUPUI, Indianapolis, IN 46202. *Correspondence between geometric and differential definitions of the sine and cosine.*

In textbooks, the familiar sine and cosine functions appear in two forms: geometric, in the treatment of unit circles and triangles, and differential, as solutions of differential equations. These two forms correspond to two different definitions of trigonometric functions. By using elementary geometry and elementary calculus, it is shown that the two definitions are equivalent. This treatment also addresses the connection between circular and harmonic motion in a more abstract form. This approach can help students enhance their ability to think abstractly in addition to acquiring more insight into trigonometric functions. (Received September 17, 2013)

2010 MATHEMATICS SUBJECT CLASSIFICATION

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